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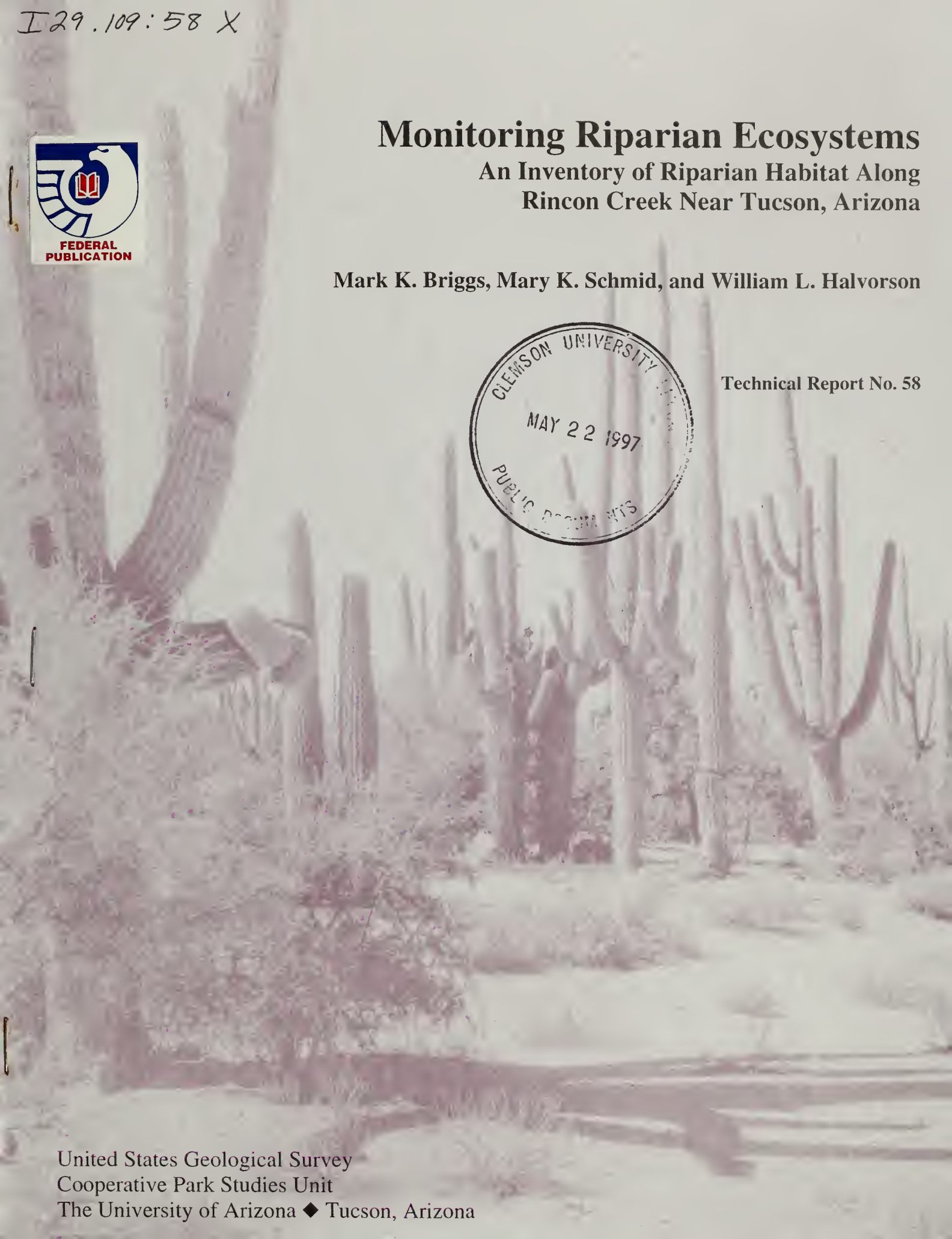

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Monitoring Riparian Ecosystems

An Inventory of Riparian Habitat Along Rincon Creek Near Tucson, Arizona

Mark K. Briggs, Mary K. Schmid, and William L. Halvorson

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Abstract

A 12-km reach of the Rincon Creek southeast of Tucson, Arizona, was used to establish the basis for evaluating the consequences of development on riparian habitats. During the next 10 years, the Rocking K Ranch, a 1,801-ha property through which Rincon Creek passes, will be extensively developed, and the degraded reach of the creek that lies within the ranch will be restored. A baseline inventory of Rincon Creek's riparian habitat was completed prior to major development. Comparing the results of future inventories to the baseline database will provide a unique opportunity to assess in detail the impacts of development on riparian habitat. Such an assessment will contribute significantly to the understanding of how development alters riparian habitat processes and how healthy riparian habitats can be protected in an urbanizing environment. This project combines an assessment of riparian plant communities with an evaluation of groundwater, streamflow, sediment movement, and channel morphology. The strategies and protocols used to conduct the inventory of riparian habitat along Rincon Creek provide a resource for monitoring efforts at other riparian sites in the desert Southwest.

Introduction

Background

Riparian ecosystems in many parts of the Southwest have become degraded and some have disappeared altogether (Warner 1979b). Degradation of Southwestern riparian habitat is well documented. Examples include areas along Dry Creek (McBride and Strahan 1981), the Carmel River (Kandolf and Curry 1984) and the lower San Lorenzo River (Griggs 1984), California; the San Pedro River (Zimmerman 1969), Sonoita Creek (Glinski 1977), the Gila River (Minckley and Clark 1984) and the Santa Cruz River (Betancourt and Turner, forthcoming), Arizona; and the Rio Puerco, New Mexico (Elliott 1979). This loss of habitat is due in large part to the effects of human activities (U.S. Council on Environmental Quality 1978; Warner 1979).

The decline of native riparian habitat has affected many wildlife species. Although riparian habitat comprises only a small percent of the total land area of Arizona, it is inordinately important to wildlife (Johnson and Jones 1977; Ohmart and Anderson 1974, 1982, 1986). Studies by Gaines (1977) in California; Carothers et al. (1974), Anderson and Ohmart (1984), Rice et al. (1984) in Arizona; and Hubbard (1971), and Hink and Ohmart (1984) in New Mexico confirm the high value of riparian habitat to wildlife. The importance of this habitat to wildlife, combined with its rapid decline, has made the protection and restoration of riparian habitat a prominent conservation issue.

As the human population in the Southwest continues to grow, urbanization will increasingly affect riparian ecosystems, often contributing to their degradation. Riparian areas are directly degraded by development when they are removed to make way for construction and flood control projects. Equally important are the many indirect effects of urbanization on riparian ecosystems, notably through groundwater decline, alteration of natural flood flows, and changes in the way sediment and water run off the land. For example, nearby development can significantly degrade the condition of riparian habitat by reducing the amount of water available for plant use, as flood control projects alter streamflow and groundwater pumping drops the saturated zone of the soil profile below the shallow root systems of phreatophytes.

However, the indirect effects of development on riparian habitat have not yet been studied extensively. Judd et al. (1971) and Stromberg et al. (1992) studied the effects of groundwater decline on mesquite bosques, but these studies are rare exceptions. Increasing our understanding of how development affects the condition of riparian habitat will significantly improve our ability to reduce the impacts of development on healthy riparian areas, as well as to improve the effectiveness of restoration strategies for riparian habitat that is already degraded.

Although many riparian restoration projects have successfully improved riparian habitat conditions, many other restoration efforts have been ineffective. This is often due to a lack of understanding of the causes of degradation and how land use changes can directly and indirectly affect the condition of these important habitats. Improving the effectiveness of riparian conservation strategies can only be accomplished by increasing our understanding of how riparian habitat becomes degraded.

Rincon Creek Monitoring Project

For the project described in this report we used a significant reach of Rincon Creek southeast of Tucson, Arizona, as a living laboratory to establish the basis for evaluating the consequences of development on riparian habitats. The 12-km reach being studied currently passes through low-density housing, abandoned agricultural land, and mesquite bosques. However, during the next 10 years, the Rocking K Ranch, a 1,801-ha property through which Rincon Creek passes, will be extensively developed, and the degraded reach of the creek that lies within the ranch will be restored once development begins.

Since the initial, baseline inventory of Rincon Creek's riparian habitat was completed prior to major development, comparing the results of future inventories to the baseline database will provide a unique opportunity to assess in detail the impacts of development on riparian habitat. Such an assessment will contribute significantly to the understanding of how development alters riparian habitat processes and how healthy riparian habitats can be protected in an urbanizing environment. In addition, the restoration of the reach of Rincon Creek that passes through the Rocking K Ranch will provide an opportunity to assess the effectiveness of riparian restoration in an urbanizing landscape.

A critical aspect of this project is that it combines an assessment of riparian plant communities with an evaluation of groundwater, streamflow, sediment movement, and channel morphology, all important factors in determining the overall health of a riparian ecosystem. Degraded riparian ecosystems are often characterized by reduced plant community density, diversity, and volume, and are often associated with altered hydrologic characteristics and unstable alluvial channels. Determining how these ecosystem characteristics are influenced by human activities (e.g., changes in land use such as development) will provide insight into not only how these important ecosystems become degraded, but also how to most effectively improve the condition of degraded riparian habitat and prevent the degradation of healthy riparian areas.

The Rocking K Development

The land bordering the 3-km reach Rincon Creek that passes through the Rocking K Ranch will experience extensive urbanization during the next 10 years. The Rocking K specific plan proposes a mixed-use, resort-oriented community that will include a variety of residential densities and areas, 2 resorts and golf courses, retail space, research and development, and a resort village center with office, retail, and higher density residential development.

Proposed Restoration

A condition of the Rocking K Specific Plan calls for the restoration of the Rincon Creek reach that passes through the Rocking K. The purpose of this restoration project is to reestablish a riparian environment along Rincon Creek by revegetating the heavily disturbed lands and reforming the Rincon Creek channel to a more natural state. As outlined in the Rocking K Specific Plan, the developer will work with Pima County Department of Flood Control and the Rincon Institute to develop strategies that will improve the overall ecological condition of this reach. The preliminary restoration plan calls for the re-establishment of a riparian woodland that

is dominated by large, native riparian trees, including *Prosopis velutina*, *Juglans major*, *Platanus wrightii*, and *Populus fremontii*.

Objectives of this Report

This report describes the methods and results of the initial baseline Rincon Creek riparian habitat inventory. Specifically, permanent transects were established across the Rincon Creek channel morphology and plant community characteristics; groundwater monitoring was initiated at several pre-existing wells; crest stage gauges and scour chains were installed for monitoring streamflow and sediment changes in the channel; photo points were established to document current conditions at each study site; and a geographical information system (GIS) database containing all data collected by this baseline inventory was created.

The report has 3 principal objectives:

1. **To improve our understanding of how urbanization affects the condition of riparian habitat.**

   Performing this inventory prior to the onset of construction offers a rare opportunity to assess how urbanization influences riparian habitat conditions. The information contained in this report provides the foundation for a long-term riparian habitat monitoring program that will evaluate the impacts of urbanization on Rincon Creek's riparian habitat. Subsequent inventories will be performed every 2–5 years, depending on funding. Comparing the results of future inventories to this baseline inventory will allow assessment of how urbanization affects riparian plant communities and the abiotic processes that are so important in determining their health (channel morphology, streamflow, sediment movement, and groundwater levels).

   A better understanding of the impacts of development on riparian habitat will also improve the ability of resource managers and land use planners to mitigate those impacts before the habitat becomes degraded and wildlife resources adversely affected. For example, evaluating the effects of development on sediment movement and channel stability will improve our understanding of how to alter future construction and development plans to lessen their impact on riparian areas.

   Data collected in future inventories will be added to the GIS database in order to create a dynamic model that will allow prediction of habitat changes under different conditions. For example, once the various data (groundwater, hydrologic, streamside vegetation, channel morphology) from a second inventory are incorporated in the GIS database, land managers will be able to predict riparian habitat changes given a specified change in groundwater conditions.

2. **To improve our understanding of how to restore degraded riparian habitat.**

The upcoming restoration of the reach of Rincon Creek that passes through the Rocking K Ranch provides another unique opportunity: to assess in detail the effectiveness of specific techniques for restoring a damaged riparian habitat in an urbanizing setting. Future inventories of the reach will be modified so that the effectiveness of the restoration effort can be evaluated in detail by measuring the survival of planted vegetation, channel stability, wildlife use, and so forth. Since the monitoring project includes an evaluation of Rincon Creek's hydrologic characteristics, future inventories will also allow an assessment of how riparian restoration influences streamflow characteristics and transmission losses.

3. **To provide a resource for other riparian habitat monitoring efforts.**

The strategies and protocols used to conduct the inventory of riparian habitat along Rincon Creek are described in this report so that it can be used as a resource not only in future monitoring efforts at Rincon Creek but also for application at other riparian sites in the desert Southwest.

Study Area

Rincon Creek drains a large portion of the southwestern side of the Rincon Mountains east of Tucson, Arizona, and flows almost due west through the Rincon Valley to its confluence with Pantano Wash (Fig. 1). The Rincon Creek watershed is described in detail below. This project focuses on the lower reaches of Rincon Creek, downstream from the pediment after the creek has descended from the foot of the Rincon Mountains into the Rincon Valley. Here, channel gradients are shallow and the channel is unconfined.

Along these lower reaches, Rincon Creek flows through a variety of riparian ecosystems. Moving along Rincon Creek in a downstream direction, you will encounter plant communities dominated by such overstory species as *Populus fremontii*, *Salix gooddingii*, *Platanus wrightii*, and such understory species as *Baccharis glutinosa*. Further downstream, riparian plant communities change to an overstory dominated by *Prosopis velutina* and *Celtis laevigata*, and understories dominated by *Acacia greggii* and *Hymenoclea monogyra*.

Human impacts are not obvious until Rincon Creek passes through the Rocking K Ranch. In this area, abandoned agricultural fields dominated by such colonizing species as *Baccharis sarothroides*, *Hymenoclea monogyra*, *Ambrosia ambrosoides*, *Isocoma tenuisecta*, and *Salsola kali* are common along the floodplain.

Sixty years ago streamflow was almost perennial along this reach of Rincon Creek, and the floodplain was dominated by *Juglans major*. Interviews with long-time Rincon Valley residents tell of numerous beavers that made their homes along this reach (A. Hodge, pers. comm., 1994). Since that time, the riparian ecosystems, hydrology, and channel morphology characteristics of the Rocking K reach have been altered significantly. Today the reach flows only after heavy rains. The walnuts were removed to make way for agriculture and grazing; and groundwater pumping, channelization, and the construction of retention basins along tributaries have changed the reach's hydrology and channel morphology by influencing sediment aggradation rates (L. Lane, pers. comm., 1994). Native, riparian ecosystems are not found again until Rincon Creek leaves the Rocking K Ranch and enters Thunderhead Ranch. Here, ecosystems are once again dominated by *Prosopis velutina* and *Celtis laevigata*.

This project inventoried riparian habitat along the reach of Rincon Creek that begins 8 km upstream from the proposed Rocking K development and ends 1 km downstream from the proposed development.

Rincon Creek Watershed

Location of Watershed

The Rincon Creek watershed is located in the Rincon Valley on the southwest side of the Rincon Mountains, in the "corner" formed by Tanque Verde Ridge and Mica Mountain to the north and Rincon Peak to the east (Fig. 1). The watershed drains approximately 19,061 ha, and is bordered on the south and west by Pantano Wash, into which Rincon Creek drains at its western-most point. Pantano Wash follows a line of truncation of a westward sloping alluvial plain, south of which lie the Whetstone and Santa Rita mountains; to the west is the Tucson/Santa Cruz Basin. Rincon Creek is an east-west incision of this plain close to its northern edge, where the alluvium laps upon the bedrock of the Rincon Mountains (Halpenny 1986).

Approximately half of the Rincon Creek watershed lies within Saguaro National Park; a small portion on the eastern end is located in Coronado National Forest. The remainder of the watershed is privately held land that is primarily undeveloped at the present time.

Geology, Hydrology, and Soils

Geologic Setting

The geologic history of the Rincon Creek watershed is complex, consisting of events of different ages, processes of rock emplacement and styles of deformation. The principal structural feature of the Rincon Mountains is the Rincon gneiss dome, a composite dome that has crests near Mica Mountain, Tanque Verde Peak, and Rincon Peak. The rocks underlying the dome and adjacent terrain are composed of core rocks, carapace rocks, and overlapping basin deposits (Davis et al. 1987).

Most of the core rocks belong to the Santa Catalina Group of gneissic rocks and are of Precambrian age. During early Precambrian time, the oldest rocks (Pinal Schist) were intruded first by Continental Granodiorite and then by Wrong Mountain Quartz Monzonite; these rocks were subsequently deformed and recrystallized. The carapace, or covering mantle, consists of a lower plate of Precambrian Y age dynamically metamorphosed rocks, a middle plate of Precambrian Y age Rincon Valley Granodiorite, and an upper plate of Precambrian Y age to Cretaceous age unmetamorphosed sedimentary rocks (from late Precambrian time through the Early Cretaceous period, the area was a relatively stable shallow marine basin, and received sedimentary material). The oldest of the onlapping basin deposits is the Pantano Formation, which was formed during the Oligocene Epoch (Davis et al. 1987).

By the time of the Oligocene Epoch, the core rocks were reheated at great depth and plastically deformed into the Rincon gneiss dome. As the dome continued to rise, the onlapping basin deposits moved downward and laterally, and some of the carapace rocks and a few core rocks moved down the flanks of the dome. Currently, on the south and west flanks of the dome (the upper portions of the Rincon Creek watershed), only small lenses of the lower plate of the carapace are preserved beneath a thick portion of the middle plate, and in many places the upper

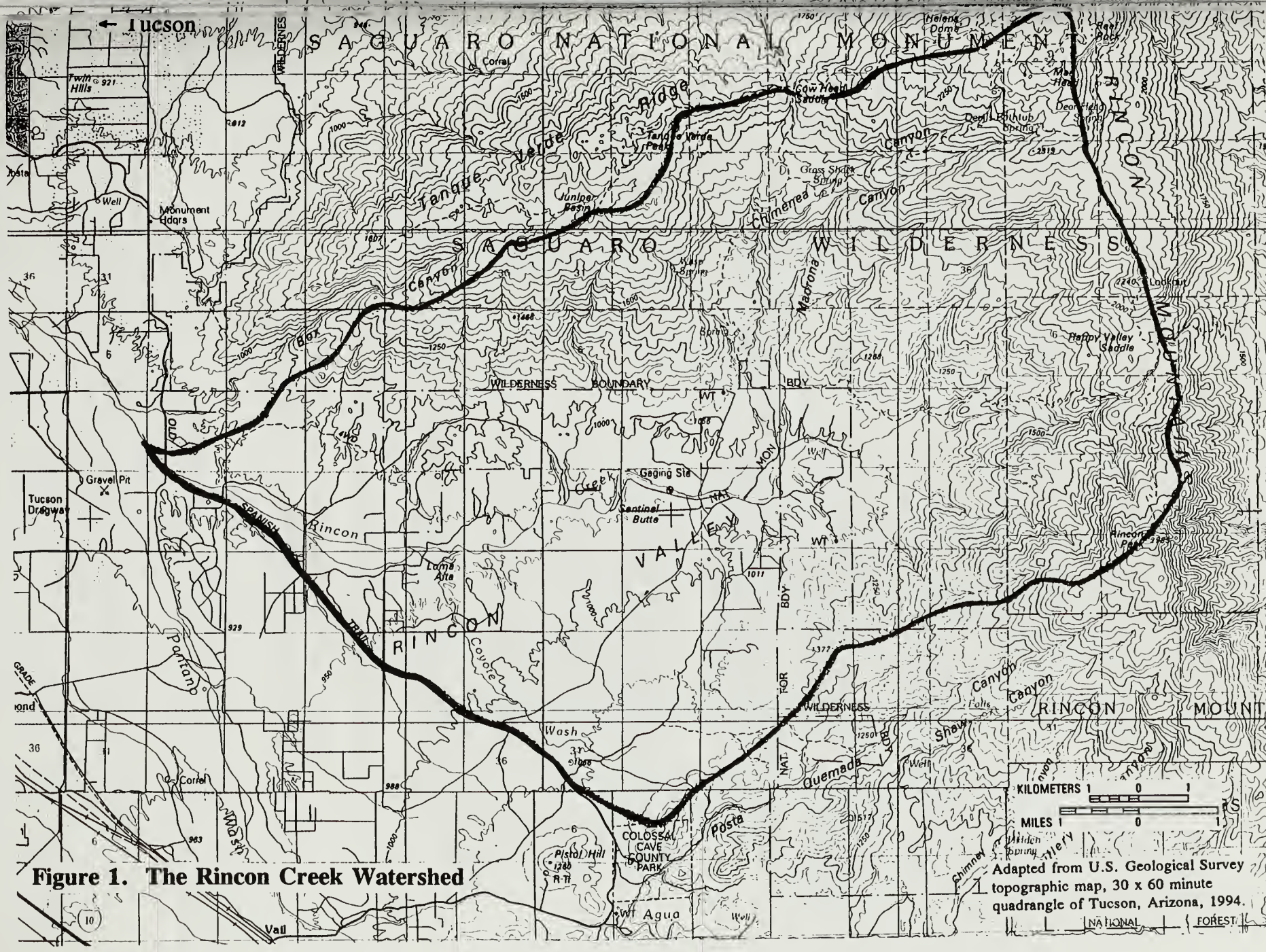

Figure 1. The Rincon Creek Watershed

plate rests directly on the core gneiss. The Pantano Formation (see Geologic Units below) lies upon the carapace in some locations, while it lies upon the core along the segment of the Santa Catalina fault (see next paragraph) at the foot of the Rincon Mountains. Massive slumping and rapid alluvial transport are still continuing responses to the topographic imbalance brought about by the rising of the dome (Davis et al. 1987).

Two major faults pass through the Rincon Creek watershed. The Santa Catalina Fault, which trends primarily westward in the northern part of the watershed, is downthrown by several hundred feet to the south. The Pantano Fault, which extends north-northwestward across the watershed just east of Pantano Wash, is downthrown to the west-southwest by approximately 240 m (Halpenny and Halpenny 1985). This fault has important hydrogeologic implications for the area (see Hydrogeology below).

Geologic Units

The geologic units that occur in the Rincon Creek watershed are, from youngest to oldest (Halpenny and Halpenny 1985):

Younger Alluvium (recent stream and floodplain deposits underlying the lowermost 7–8 km of Rincon Creek and its confluence with Pantano Wash)
Holocene gravel, coarse sand, and a few silt lenses

Terrace Deposits (occur only along the western edge of Pantano Wash's floodplain)
Holocene gravel and gravelly sand

Older Alluvium, undifferentiated
Pleistocene gravel and gravelly sand to sandy silt

Fort Lowell Formation
Pleistocene gravel to clayey silt

Tinaja Beds
Miocene and Pliocene sandy gravel to gypsiferous clayey silt and mudstone

Pantano Formation
Oligocene gravel, sandstone, mudstone, and gypsiferous mudstone

Sedimentary Rocks, undifferentiated
Precambrian conglomerate, sandstone, mudstone, shale, and some limestone; also Paleozoic limestone and quartzite

Intrusive and Metamorphic Rocks
Precambrian granite, granitic gneiss, and schist

The following units were unearthed at a well within the study area south of Rincon Creek (Halpenny 1986):

Depth below well casing (ft)	
0–40	undifferentiated alluvial deposits
40–130	Fort Lowell Formation
130–490	Tinaja beds
490–750	Pantano Formation
750–757	intrusive and metamorphic rocks

Hydrogeology

Of the geologic units described above, groundwater in the Rincon Creek watershed occurs principally in the Fort Lowell Formation and the underlying Tinaja beds. The Pantano Formation is a water-bearing unit of less importance, and perched groundwater occurs only temporarily during wet years in the younger and older alluvium. Groundwater moves through the Rincon Valley's aquifer system from northeast to southwest; southwest of Rincon Creek, it moves across the Pantano Fault and into the Santa Cruz/Tucson Basin (Halpenny and Halpenny 1985). The Pantano Fault constitutes a line of hydrogeologic separation between occurrence and utilization of groundwater in the Rincon Valley and the Santa Cruz/Tucson Basin; that is, the fault has prevented water table declines in the Tucson Basin from affecting the Rincon Valley's groundwater supply (Halpenny 1986).

The average depth of the water table in the Rincon Valley is 76 m; the saturated thickness of alluvium is estimated to be 122 m (Halpenny 1986). The aquifer system fluctuates in response to mountain front recharge and runoff in Rincon Creek (and, of course, withdrawals from wells). Although recharge along Rincon Creek contributes to the Rincon Valley groundwater supply, recharge along Pantano Wash does not (Halpenny and Halpenny 1985). Extensive water level data from the 1940s through 1980 exhibit a cyclical pattern of decline during dry periods, increase during wet periods, and a slightly shallower (or higher) water level in 1980 than during the 1940s. This 30-year-plus trend indicates that the Rincon Valley's aquifer system is effectively in balance between long-term recharge and long-term natural discharge plus historic withdrawals of water (Halpenny 1986). Osterkamp (1973) calculated the long-term average annual groundwater recharge in the Rincon Valley to be 1,837 ha-feet per year.

Surface Water

Lower Rincon Creek and Pantano Wash are ephemeral streams, flowing only in response to runoff producing storms (Halpenny 1986). Groundwater contour maps show that practically all flow in Rincon Creek sinks into the ground before it reaches the creek's confluence with Pantano Wash (Halpenny and Halpenny 1985).

Mean annual discharge at the U.S. Geological Survey crest-stage partial-record station on Rincon Creek during 1953–1974 and 1990–1992 was 5.9 ft^3/sec (U.S. Geological Survey 1993). Monthly means clearly reflect the Sonoran Desert's bi-seasonal precipitation pattern: the highest discharges occur in the winter rainy season (December–March) and the summer monsoon season (primarily in August); almost no flow occurs in November, May, or June.

Soils

Soil characteristics in the Rincon Creek watershed are variable, ranging from sandy, well-drained river bottoms to areas of rock outcrops (McGovern, MacVittie, Lodge & Dean, Inc., et al., 1991). For example, the carapace rock Rincon Valley Granodiorite (a granitic rock made up of an assemblage of biotite or biotite and hornblende, plus quartz, 2 feldspars, and trace minerals) is typically found exposed in the southeastern part of the watershed (Davis et al. 1987). The U.S. Soil Conservation Service (1985) has mapped 14 soil types in the area, which are combined into 4 soil units made up of soil types with similar characteristics. These soil units are identified as:

Category 1	Four soil types found in and around Rincon Creek and its larger tributaries, generally sandy loams and other soils typical of river bottoms and nearly level low stream terraces (characteristics: deep; well to excessively drained; rapid to slow permeability; low to high available water capacity; effective rooting depth of 150 cm or greater)
Category 2	Three soil types primarily found on gently sloping fan terraces, generally gravelly, sandy loams (characteristics: deep; well drained; moderate to slow permeability; low to high available water capacity; effective rooting depth of 150 cm or greater)
Category 3	Four soil types found on moderately sloping foothills and hillsides, generally gravelly and cobbly sandy loams (characteristics: shallow to very shallow - 1 soil type ranges from shallow to deep; well drained; moderately rapid to slow permeability; very low to low available water capacity; effective rooting depth of 10–50 cm)
Category 4	Three rock outcrop and soil complexes found on steeper hill and mountain slopes, generally intermingled soil and barren rock with a higher percentage of rock outcrops near hill and mountaintops (characteristics: shallow to very shallow; well to excessively drained; moderate to moderately rapid permeability; very low available water capacity; effective rooting depth of 10–50 cm)

In general, soils occurring near drainages are deep and have a higher available water capacity, while soils occurring on slopes are shallow and have a very low available water capacity.

Climate

The climate of the Rincon Creek watershed is classified as dry subtropical desert, which is characterized by a strong seasonal cycle in annual temperatures, with hot summers and a distinct cool to cold winter season. This cold season is due in part to invasions of cold continental polar air masses from higher latitudes. Precipitation is low with 2 maxima, 1 in winter (December–March) and 1 in summer (August). Winter rainfall is produced by incursions of mid-latitude cyclones, while summer rains are caused by invasion of maritime tropical air masses that result in thunderstorms (Strahler and Strahler 1979).

Temperature and precipitation in the watershed also vary with elevation. In the summer, temperatures on the valley floor often exceed 38° C while typically only reaching the 20s at higher elevations. Winter temperatures below 1,400 m are mild, with freezing temperatures rarely lasting longer than 24 hours. At higher elevations, the average maximum temperature during January is 6.5° C; the average minimum is −4° C. Annual precipitation in the Rincon Mountains averages 32 cm at the foot and 70 cm at high elevations (Bowers 1991). Roughly 45% of the annual total falls between November and March, while 30% falls in July and August.

Topography and Plant Communities

Rincon Creek's headwaters originate on the southern slopes of Mica Mountain and the western slopes of Rincon Peak, at an elevation of approximately 2,400 m (Fig. 1). The elevation at the confluence of Rincon Creek and Pantano Wash is 852 m. North of the creek, the predominantly rocky and rough land rises steeply to Tanque Verde Ridge and Mica Mountain.

Generally, plant communities range from Sonoran Desert scrub at low elevations, grading into desert grassland at elevations of 1,219–1,524 m, which in turn gives way to pine-oak woodland at higher elevations (1,341–1,859 m). Riparian woodland occurs along Rincon Creek and its major tributaries (Bowers and McLaughlin 1987).

Desert Scrub

Desert scrub plant communities are comprised of species from the Arizona Upland subdivision of the Sonoran Desert, which is characterized by the presence of numerous cacti and the drought-deciduous habit of many of the trees and shrubs (Turner and Brown 1982). Dominant overstory species include *Prosopis velutina*, *Cercidium microphyllum* and *C. floridum*, *Parkinsonia aculeata*, *Carnegiea gigantea*, and *Fouquieria splendens*. *Phoradendron californicum* is a common parasite of leguminous trees. Understory species include *Ambrosia deltoidea*, *Isocoma tenuisecta*, *Encelia farinosa*, a wide variety of *Opuntia* spp., *Mammillaria microcarpa, Acacia greggii* and *A. constricta*, *Ferocactus wislizenii* and *F. acanthodes*, *Yucca elata*, *Opuntia engelmannii* and *O. phaeacantha* var. *major*, *Agave deserti*, *Lycium berlandieri* and *L. pallidum*, *Simmondsia chinensis*, *Ephedra trifurca*, *Celtis pallida*, *Atriplex canescens*, *Larrea tridentata*, *Jatropha cardiophylla*, *Calliandra eriophylla*, and *Koeberlinia spinosa*. Common grasses include *Bouteloua curtipendula*, various *Muhlenbergia* spp., *Aristida longiseta* and many others (Turner and Brown 1982; Bowers and McLaughlin 1987; McMahon 1990; Bowers 1993; Turner et al. 1995; pers. obs.).

Desert Grassland

Desert grassland species are variable and dominated by a large number of perennial grasses, which generally flower with summer rains. Among the most important are *Heteropogon contortus*, and *Bouteloua hirsuta* and *B.* spp., *Hilaria belangeri*, *Eragrostis intermedia*, *Muhlenbergia emersleyi*, *Schizachyrium cirratum*, *Andropogon barbinodis*, *Lycurus setosus*, *Digitaria californica*, and others. Many shrub and stem succulents are also present, including *Dasylirion wheeleri*, *Nolina microcarpa*, *Opuntia engelmannii*, *Opuntia* spp., *Yucca elata*, *Jatropha cardiophylla*, *Aloysia wrightii*, *Calliandra eriophylla*, *Brickellia venosa*, *Mimosa biuncifera*, *Gossypium thurberi*, *Eriogonum wrightii*, and more. A few widely scattered trees

occur, including *Prosopis velutina*, *Juniperus deppeana*, and *Quercus oblongifolia*, as well as several small *Mammillaria* spp. (Kearney and Peebles 1960; Bowers and McLaughlin 1987; USDA Forest Service 1988; Bowers 1991).

In desert grassland areas that were heavily grazed until the mid 1970s (e.g., the level benches above Madrona Ranger Station), species composition has been altered. These areas are now dominated by *Prosopis velutina*, *Isocoma tenuisecta*, and *Opuntia engelmannii*, and show little recovery even after 20 years (Bowers and McLaughlin 1987).

Pine-oak Woodland

Pine-oak woodland plant communities are variable in both physiognomy and species composition. The trees often form an open woodland, but the communities at some locations are chaparral-like, with occasional *Quercus emoryi* and *Pinus discolor* struggling out of thickets of *Arctostaphylos pungens* and *A. pringlei*. *Quercus emoryi* and *Q. arizonica* dominate at lower elevations, while *Juniperus deppeana* and *Pinus discolor* dominate at higher elevations. *Quercus oblongifolia* appears where pine-oak woodland blends with desert grassland. Typical shrub species include *Arctostaphylos pungens*, *Garrya wrightii*, *Yucca schottii*, and *Nolina microcarpa*; other understory species including *Rhus trilobata*, *Rhamnus* spp., *Acacia angustissima*, *Agave schottii* and *A. palmeri*, *Opuntia spinosior*, *Opuntia engelmannii*, and *Eriodictyon angustifolium* range from scarce to numerous. The understory is rich in species at lower elevations, but declines at higher elevations, where woody species cover is close to 100%. The scattered tree canopy and bi-seasonal precipitation pattern produce a heterogeneous environment in which a rich and distinctive variety of herb species flourish, 1 flora in fall and another in spring (Kearney and Peebles 1960; Elmore 1976; Bowers and McLaughlin 1987).

Riparian Woodland

The species composition of riparian woodland is highly variable and often markedly different than surrounding plant communities. In addition to typical riparian species, species normally found at higher elevations are sometimes found (Bowers and McLaughlin 1987). Riparian woodland in the Rincon Mountains is dominated by *Platanus wrightii*, *Salix gooddingii*, *Fraxinus velutina*, *Alnus oblongifolia*, *Juglans major*, *Quercus arizonica*, *Populus fremontii*, and *Juniperus deppeana*. Non-riparian species such as *Pseudotsuga menziesii* and *Cupressus arizonica* are sometimes scattered in riparian habitat at lower elevations (Bowers and McLaughlin 1987; Bowers 1993). Other species found along Rincon Creek and its tributaries include *Prosopis velutina*, *Acacia greggii* and *A. constricta*, *Lycium pallidum*, *Celtis laevigata* and *C. pallida*, *Chilopsis linearis*, *Hymenoclea monogyra*, *Ziziphus obtusifolia*, *Baccharis sarothroides*, and *Atriplex canescens*.

Land Use History of the Rincon Valley

This section describes some of the major land use activities that have occurred in the Rincon Valley, and how some of these activities may have affected the natural resources of the Rincon Creek watershed. Although the focus is on land use activities that occurred during post-development times (since the 1880s), the valley's prehistoric setting (pre-200 B.C.–A.D. 1500) and events during the 17th and 18th centuries are also briefly described.

Prehistory

Numerous prehistoric habitation sites ranging from large villages to farmsteads, as well as rock shelters, rock quarries, petroglyph sites, and clusters of agricultural features including check dams and irrigation canals, indicate that the Rincon Valley experienced fairly extensive human activity during prehistoric times. In fact, prehistoric sites are more common than sites dating to historic times (McGovern, MacVittie, Lodge & Dean, Inc., et al., 1991).

Most prehistoric sites are located north of Rincon Creek, with the majority of habitation sites occurring adjacent to the creek's confluences with major tributaries. Sites from the Tanque Verde phase of the Hohokam Classic period (A.D. 1200–1350) predominate, although Rincon phase (A.D. 900–1500) materials and some earlier Ceramic period sites are also present. In addition, several Archaic period (pre-200 B.C.) sites have been recorded (McGovern, MacVittie, Lodge & Dean, Inc., et al., 1991).

1600–1850

No historical data specific to the Rincon Valley are available for this time period; as stated above, only prehistoric sites (from the 1500s and earlier) and sites from the late 1800s and early 1900s have been discovered. This is most likely due to the valley's isolated location as well as raiding by the Apaches, who migrated into the region in the late 16th century, about the same time as the first Spanish expeditions reached Arizona and New Mexico from the south (Baldwin 1965).

Although there are no archaeological or historical records of human activities in the Rincon Valley until after 1850, impacts on the environment and native people of the larger Tucson-Santa Cruz Basin within which the valley lies can be attributed to the arrival of Spanish settlers in the 1600s. The following events can reasonably be assumed to have had some impact on the resources of the Rincon Valley.

After Franciscan Father Eusebio Kino established San Xavier mission near the Santa Cruz River on the opposite (west) side of the Tucson Basin in the 1690s, the patterns and kinds of land uses in the area changed. Following their conversion to Christianity, the native people resettled near the mission and began to cultivate a variety of European crops, relying less on native foods and agricultural practices. Mining by European settlers had some local impacts as well, primarily from harvesting of wood for timber and fuel (Arizona Daily Star, 1933; Hastings and Turner 1965).

The Rincon Valley lies along a natural pass between the Rincon Mountains to the north and the Empire, Whetstone and Santa Rita Mountains to the south. It was therefore at the very least passed through by travelers going to and from the Tucson-Santa Cruz Basin and the San Pedro River or points further east.

The Spaniards also brought cattle with them, commencing the history of cattle grazing in the Southwest (Hastings and Turner 1965). By the early 1800s, Mexican cattle ranchers had developed large ranches throughout southern Arizona (Arizona Daily Star 1933). Increased

Apache raiding drove some of these ranchers from the area, resulting in many wild herds of livestock roaming the region in the mid 1800s (Hastings and Turner 1965).

1850-1900

The Rincon Valley became part of the United States in 1853, with the signing of the Gadsden Purchase. In 1857, an Overland Mail Stage route was established that ran west from the San Pedro River at Benson, south of the Rincon Mountains to Tucson, and on to Yuma and California (Conkling and Conkling 1947). This route crossed the south and west sides of the Rincon Valley. The Southern Pacific Railroad, completed in 1880, followed essentially the same route as the stageline. This link to other settlements provided expanded economic opportunities and influenced the culture in the area. For example, the railroad station at Vail supplied small-scale mining operations in the Whetstone, Empire, and Santa Rita mountains to the south, and became an important shipping point for the valley's settlers (Myrick 1975).

Although there is some evidence that La Cienega Ranch (near what is now the town of Vail) existed in the 1860s, most settlement in the Rincon Valley probably occurred following establishment of Fort Lowell on the Rillito River east of Tucson in 1873 (SWCA, Inc. 1989). Accounts from the 1870s tell of ranchers in the valley periodically retreating from Apache raids to the safety of Tucson (Cosulich 1932). There are also reports of prehistoric irrigation canals being utilized by Mormon settlers in the latter half of the 19th century (Arizona Daily Star 1933). By the late 1800s, a number of families had settled along Rincon Creek, growing crops and raising beef and dairy cattle (Miller n.d.; SWCA, Inc. 1989; Rasmussen 1995). Some settlers also made a living by cutting wood and producing quicklime, made by burning limestone in kilns (Simpson and Wells 1984).

Easy access to expanding beef markets in the eastern United States provided by the railroad system, and subjugation of the Apaches in the 1880s, fostered a thriving livestock industry in the area. Some cattle ranges were already reaching their grazing limit by the late 1880s. At this time, southeastern Arizona experienced several years of major floods, which dramatically altered the region's stream systems. Flooding peaked in 1890, when both the Rillito and Santa Cruz rivers were denuded of vegetation and carved into deep channels. In conjunction with unusually high precipitation, overgrazing, and the clearing of riparian vegetation for fuel and building materials contributed to these drastic landscape changes by increasing runoff and destabilizing river banks (Hastings and Turner 1965). These events were certainly felt upstream from Tucson along Pantano Wash and Rincon Creek.

The floods of the late 1880s were followed by several dry years, which brought about severe loss of livestock and a landscape that had been grazed down to bare earth. As this denuded landscape recovered, the original grassland was invaded by tree and shrub species dominated by *Prosopis* spp. and *Opuntia phaecantha* (Hastings and Turner 1965).

1900-1960

Cattle ranching and farming were the predominant land uses in the Rincon Valley during the early 1900s. Some small-scale mining, probably for low-grade copper deposits, also took place.

Quicklime production continued until approximately 1920, when neighboring ranchers objected to the depletion of *Cercidium floridum* and *C. microphyllum* and *Prosopis* spp. trees, which were being cut down to fuel the kilns (Simpson and Wells 1984; Rasmussen 1995).

When the Rincon Mountains became part of a National Forest Reserve (now Coronado National Forest) in 1902, at least 1 homestead at the east end of the Rincon Valley was relinquished to the Forest Service. Some of the federal land was eventually returned to the state of Arizona, and subsequently leased and homesteaded (Miller n.d.). In 1933, the portion of the national forest to the north of the valley was designated as Saguaro National Monument; this area became a national park on 14 October 1994. Although these lands have been "protected" by these designations, grazing was permitted on the monument until 1958 (Turner 1992) and currently continues on Forest Service land (T. Quinn, pers. comm., 1996).

Long-time Rincon Valley resident Ted Knipe recounts that when his family moved to the valley in 1911, they and their mostly Mexican-American neighbors typically owned 16-ha ranches on which they cultivated a few hectares of crops (such as barley, corn, beans, squash, apricots, and peaches) and raised chickens and dairy cows (Henry 1991). Knipe and Ray Geer, another Rincon Valley resident who grew up on the Loma Alta Ranch on Rincon Creek, describe how all the ranchers in the valley ran their beef cattle herds together on the open range, which included the unfenced Saguaro National Monument (Henry 1991; R. Geer, pers. comm., 1996).

1960s–Present

During the second half of the century, land use in the Rincon Valley has shifted from ranching to private residential development. Beginning in the 1960s, some of the traditional 16-ha-plus ranches were subdivided into 4–8 ha "ranchettes." By the 1980s, several ranches in the valley had been transformed into 0.40-ha private residential neighborhoods (Rasmussen 1995; A. Gibson, pers. comm., 1996). Development of an extensive mixed-use, resort-oriented planned community on the Rocking K Ranch will begin in the late 1990s.

The legacy of cattle ranching can still be seen in the Rincon Valley, even in areas that are no longer grazed. In desert scrub areas, the grasses and wildflowers preferred by cattle are now dominated by unpalatable weedy shrubs such as *Isocoma tenuisecta* (Bowers 1991, pers. obs.). In combination with a warmer and drier trend in the regional climate, grazing has contributed to wide-scale conversion of grasslands to desert scrub (Hastings and Turner 1965). Where grazing still occurs along the more natural upper Rincon Creek, understory species are nearly absent and cattle trails across the creek have caused some bank erosion and undermining of the trees that line the channel (Rasmussen 1995; pers. obs.).

Inventory Methods

The methods used to measure the various habitat parameters in this inventory were based on those established by government agencies and experts in pertinent fields, and were modified where appropriate to fit the unique conditions at the study sites. Numerous specialists were involved in developing and evaluating the inventory methodologies, including Bruce Roundy, William Shaw, and Guy McPherson (The University of Arizona); Waite Osterkamp and John Parker (U.S. Geological Survey); and William L. Halvorson (CPSU/UA).

Location and Length of Study Sites

The location and length of study sites for this inventory were determined primarily by 2 factors. First, the realities of land ownership limited access to only certain reaches of Rincon Creek. The Rincon Institute gained permission to perform the work associated with the inventory on land within Rocking K Ranch and on several private properties up and down-stream from the Rocking K; at these locations, sites were chosen that were long enough to encompass 3 transect lines placed across the channel at random intervals of at least 40 m (see Channel Morphology Survey below). Second, study sites had to be selected so that data collected were representative of the selected reach. This required each site to be positioned in an area uninfluenced by unique geologic features, tributaries, or human structures (e.g., bridges or roads) that affect streamflow and vegetation.

Four study sites were identified along a 12-km reach of Rincon Creek (Fig. 2). Study sites A and B are located upstream from the Rocking K Ranch; study site A is 3 km upstream from Camino Loma Alta, and study site B is 0.3 km upstream from Camino Loma Alta. Study site C is located on the Rocking K Ranch, 3.9 km downstream from Camino Loma Alta, and 0.8 km upstream from Old Spanish Trail. Study site D is located downstream from the Rocking K Ranch, 4.7 km downstream from Camino Loma Alta, and 0.2 km upstream from Old Spanish Trail.

Channel Morphology Survey

Measuring channel geometry features allows streamflow characteristics to be determined indirectly based on channel characteristics formed by the water and sediment discharge of a stream (Hedman and Kastner 1977; Hedman and Osterkamp 1982). Generally, an alluvial channel's size is indicative of the water conveyed through it, and its shape is largely the result of the sediment transported along it by the stream (Hedman and Osterkamp 1982). Conducting a baseline survey of the existing physical conditions of a stream channel enables changes in the character of the stream to be monitored (Harrelson et al. 1994).

The physical characteristics of the Rincon Creek channel at each of the 4 study sites were surveyed in order to monitor changes in channel cross-sectional geometry and gain information on sediment movement through future inventories. The cross-sectional area of the active channel was also needed for calculation of peak discharges (see Crest Stage Gauges below). Data

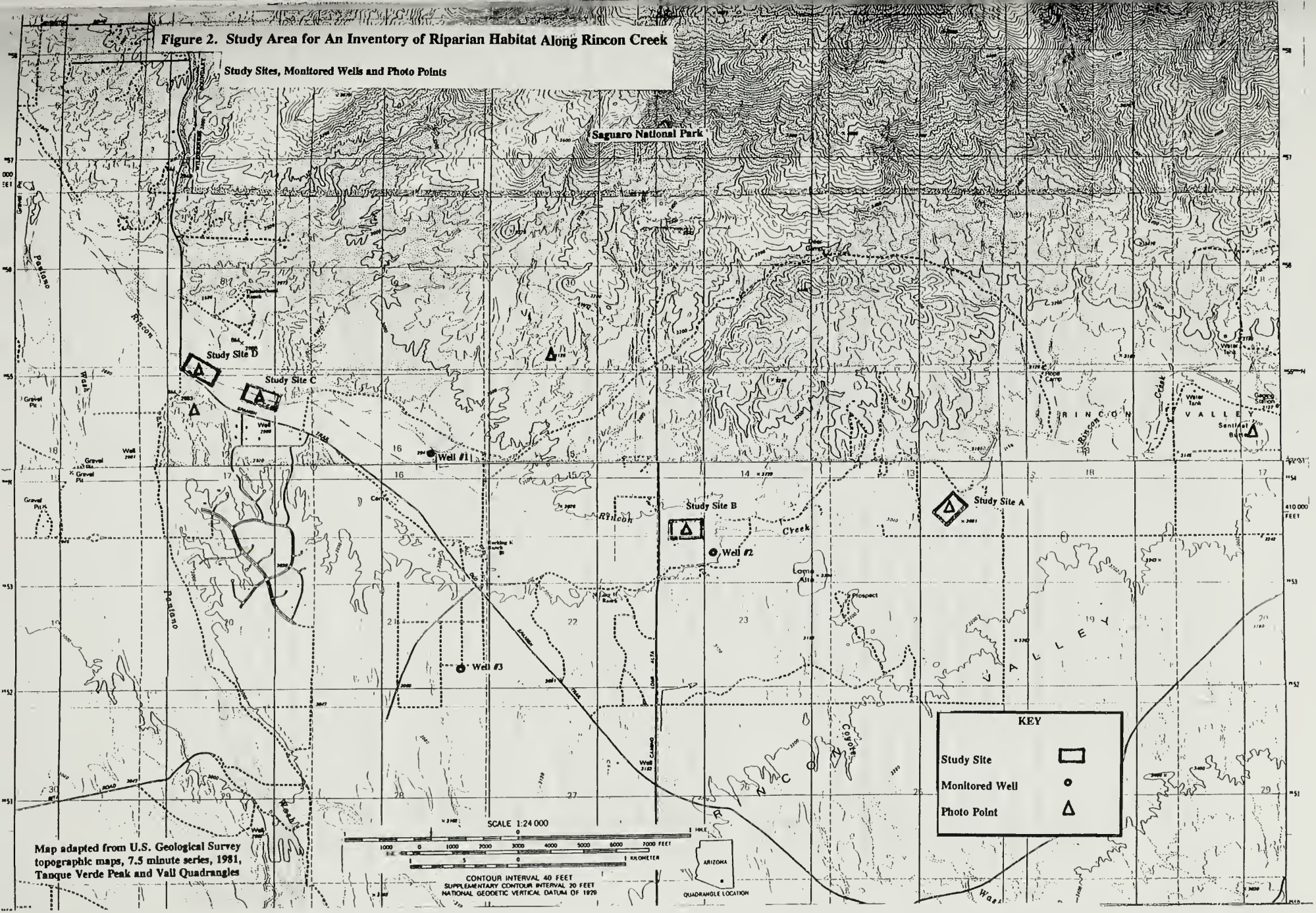
Figure 2. Study Area for An Inventory of Riparian Habitat Along Rincon Creek
Study Sites, Monitored Wells and Photo Points
Saguaro National Park
Study Site D
Study Site C
Study Site B
Study Site A
Well #1
Well #2
Well #3
Rincon Creek
RINCON VALLEY
Pantano Wash
Cienega Creek
Lomas Alta
Prospect
Coyote Wash
KEY
Study Site
Monitored Well
Photo Point
SCALE 1:24 000
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
ARIZONA
QUADRANGLE LOCATION
Map adapted from U.S. Geological Survey topographic maps, 7.5 minute series, 1981, Tanque Verde Peak and Vail Quadrangles

collection procedures and location of transect lines for measuring cross-sectional profiles followed methods described in Hedman and Kastner (1977), Hedman and Osterkamp (1982), Gordon et al. (1992), and Harrelson et al. (1994).

Three transect lines were established at each of the 4 sites by stretching a measuring tape tightly across and perpendicular to the low-flow channel. Three cross sections were surveyed at each site because the channel dimensions of width and average depth may vary along the channel. Transects were numbered sequentially in the downstream direction. The tape was extended to include a significant portion of the floodplain; transect length therefore varied between and within sites according to terrain, vegetation characteristics, and property ownership. The position of transects along the length of the study sites was randomly determined within the constraints imposed by a combination of factors including study site length, channel pattern characteristics, general streamside plant community patterns, and the extent of anthropogenic disturbances. To avoid changing the drainage area, transects were not placed immediately upstream or downstream from tributaries. Since vegetation data were also collected along the transects, they were placed at least 40 m apart so that vegetation sample plots would not overlap (see Plant Community Inventory for diagrams illustrating the location of transects and plots at each site). Study site A was the exception to these guidelines. To reflect the site's more varied topography and plant communities, 5 transects placed at 20-m intervals were established.

Cross-sectional profiles were measured using a transit (a surveyor's level), a leveling rod, and a measuring tape. Elevation readings were taken at numerous locations along each transect: all significant breaks of slope in the channel, as well as the active floodplain, bankfull elevations, and stream terraces, were measured (see Channel Morphology Data Collection Form in Appendix 2). Cross-sectional area of the active channel was calculated using Aquapac software (developed in Australia to facilitate the calculation of various parameters associated with stream environments).

To ensure relocation of transects for future inventories, permanent endpoint monuments were installed at both ends of each transect, and their locations determined with a global positioning system (GPS) receiver. The GPS coordinates of each transect monument were included in the database described below in the GIS section. Photographs of the tapes stretched across the channel along each transect line were also taken to aid in relocation.

Stream Hydrology Monitoring

Monitoring Streamflow

Streamflow characteristics are extremely significant factors in determining the overall health and trend of riparian ecosystems. Collection of streamflow data is important for evaluation of the long-term water supply needed to maintain riparian vegetation. In addition, floods rearrange streambed habitats, producing ideal seed-bed conditions for riparian plants. Relating discharge data with the form of the channel delineates over-bank flow frequency (Briggs 1996). These intricate interrelationships between riparian ecosystems and stream hydrology make the inclusion of stream hydrology in a riparian monitoring program mandatory.

Crest Stage Gauges

For this study, 6 crest stage gauges were installed to measure streamflow, 3 at study site B and 3 at study site C. Crest stage gauges measure the flood crest under conditions of transient flow. Gauge design, installation and placement followed procedures outlined in Boyer (1964), U.S. Geological Survey (1977), Gordon et al. (1992), and Harrelson et al. (1994).

Gauges were installed in the low-flow channel 200 m from one another, and their locations in relation to the permanent cross-sectional transect lines at each site were noted. Photographs of the gauges were also taken to aid in relocation. The gauges were made of 4-ft-long, 3-in-diameter PVC pipes with open, screened bottoms and vented tops that were mounted vertically on 4-in x 6-in x 10-ft posts buried in the channel to a depth of 6 ft (Fig. 3). The posts were set in 160 lbs of concrete, and were beveled on the upstream side to reduce friction and debris accumulation during flow. Each gauge contains a removable 1-in x 1-in x 4-ft wood staff wrapped with an adhering cloth and held in place by a cap on the pipe. Finely ground styrofoam pieces are placed at the bottom of the PVC pipe, where they are retained by the screen. When a flood wave passes, the water rises through the screen and lifts the styrofoam (as well as silt and other material); when the water recedes, the styrofoam is left clinging to the staff at the high water mark or "crest stage."

The gauges were checked after every large precipitation event. Any flood-crest marks were measured and recorded. The current elevation of the channel bed surface relative to a reference elevation marked on each gauge was also measured. Each gauge was reset after every peak flood event by removing all debris from the staff and restocking the styrofoam pieces as necessary (see Crest Stage Gauge Data Collection Form in Appendix 2).

Peak discharges at study sites B and C were estimated using methods described in Gordon et al. (1992) and Briggs (1996). The slope of each flood peak was obtained by measuring the elevation of the flood-crest mark relative to the established reference elevation on each gauge. Using Manning's equation, instantaneous discharge was calculated for the 2 reaches. This was accomplished by combining slope data (developed from the gauges) with a roughness coefficient and the cross-sectional area at the gauge site (calculated from the channel morphology survey). Flood peak discharges at the 2 study sites were compared to determine streamflow losses (due to percolation to groundwater) between the reaches, yielding a more accurate assessment of hydrologic conditions at the study sites.

Monitoring Sediment Movement

Changes in sediment movement and storage can have a significant impact on the stability of an unconfined alluvial stream channel (Leopold and Wolman 1957). Future inventories will quantify how urbanization influences the movement of sediment through Rincon Creek and how changes in sediment movement may affect the channel's stability. Including the measurement of sediment movement in the monitoring effort will not only improve our understanding of how significant watershed disturbances such as urbanization affect sediment movement, but also how enhanced channel instability, and the concomitant destruction of streamside riparian ecosystems, can be reduced or even prevented.

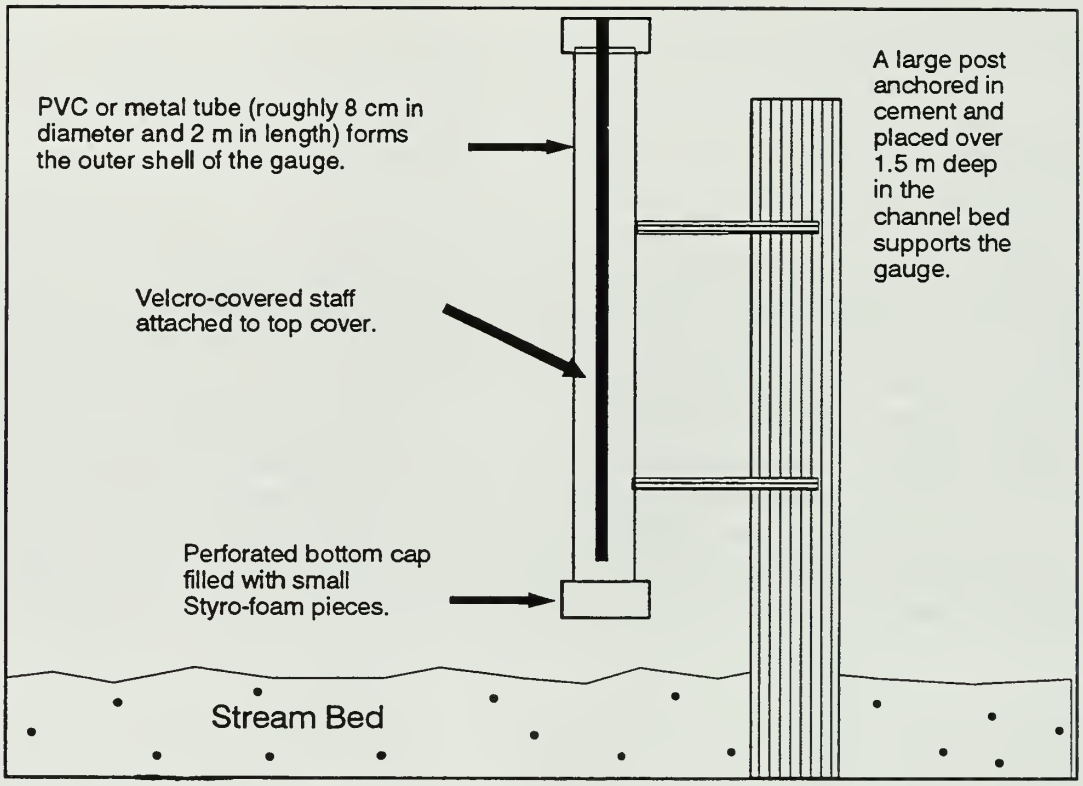
PVC or metal tube (roughly 8 cm in diameter and 2 m in length) forms the outer shell of the gauge.
A large post anchored in cement and placed over 1.5 m deep in the channel bed supports the gauge.
Velcro-covered staff attached to top cover.
Perforated bottom cap filled with small Styro-foam pieces.
Stream Bed

Figure 3. Idealized drawing of a crest stage gauge.

Scour and Fill Chains

For this study, the scour and fill technique (Gordon et al. 1992; Harrelson et al. 1994) was used to monitor sediment movement. Scour refers to the movement of bed material during a flood, and fill refers to sediment deposition that occurs as floodwaters subside and fill in scoured areas. Recording the amount of scour and fill along various parts of a drainage system provides information that describes how sediment is moving through the system.

To measure scour and fill, scour chains are installed in the channel bed. These are metal chains anchored onto metal plates and buried vertically in the channel bed (Fig. 4). When a flood scours away the bed material, the exposed chain falls flat, forming a bend. Subsequent filling reburies the chain. The amount of scour can then be determined by comparing the original length of chain buried to the length left below the bend, and the amount of fill determined by measuring the depth of sediment above the bend.

Two scour chains were installed along each of the 3 transects at study site C. The precise distance of each scour chain from transect lines, monuments and/or crest stage gauges (as well as approximate distance from the nearest bank) was measured and recorded so that they can be located in the future. Photographs of scour chain positions were also taken to aid in relocation. The initial elevation of the bed material at each site was obtained from the channel cross section data (see Channel Morphology Survey above), and the initial length of chain buried was recorded for each scour chain. These measurements allowed calculation of changes in bed elevation when the scour chains were monitored over time. Chains were excavated after peak flow events to measure any scour and fill, then straightened and reburied. If the new elevation of bed material was lower than the total length of the scour chain, the length of chain left exposed after reburial was also recorded (see Scour and Fill Data Collection Form in Appendix 2).

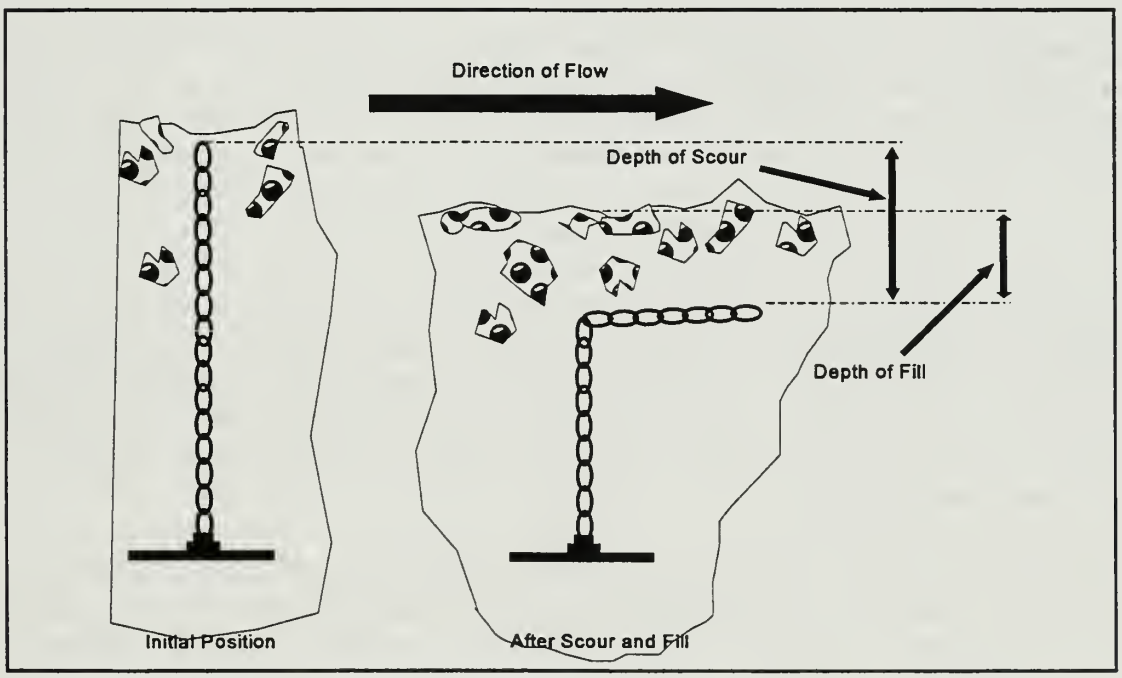

Figure 4. Measuring scour and fill using scour chains.

Groundwater Monitoring

Groundwater is a significant controlling factor in the location and survival of phreatophytic vegetation and its associated wildlife populations (Dunne and Leopold 1978). Knowledge of the subsurface water level at a riparian site may be critical to interpretation of vegetation data, and can be a valuable monitoring tool (Myers 1989). Maps of groundwater changes can be prepared from measurement of water levels in wells (Todd 1964; Todd 1980). Water levels in aquifer systems that are in a state of equilibrium between long-term recharge and long-term natural discharge plus human withdrawals will exhibit normal seasonal fluctuations reflecting dry and wet periods of the year, with little change in elevation over long periods of time (Halpenny and Halpenny 1985). If an aquifer system is in a state of disequilibrium, long-term monitoring will reveal significant changes in groundwater levels.

Groundwater data were obtained from 3 abandoned private wells using measurement techniques based on those described in Todd (1980). Abandoned wells were chosen so that measurements would not be affected by cones of depression caused by pumping, but rather would reflect actual changes in elevation of the water table. Originally, 4 abandoned well sites were included in the study design. However, 2 of these wells could not be used because the depth of the well casing was consistently above the aquifer's potentiometric surface (i.e., the wells were often dry). An abandoned well south of Old Spanish Trail was therefore added to the study in July 1995. All 3 wells are located in the Rincon Creek watershed in close proximity to the study sites (Fig. 2).

Water level was measured by lowering a weighted measuring tape into the well. Two of the wells were shallow enough that the length of submersion could be accurately read directly from the water line on the tape. For the third, much deeper well, the lower end of the tape was covered with nontoxic, water-soluble paint immediately before it was immersed so the length of submersion could be accurately read. The distance from the ground surface to the water surface was then calculated (see Data Collection Form for Groundwater Monitoring in Appendix 2). Groundwater elevations were adjusted with surface elevation differences between the well locations and the study sites.

Groundwater elevations were measured monthly by Rincon Institute staff and Rincon Valley residents who volunteered to participate in this project. Measurements were taken in the first week of each month. Volunteers were provided with the measuring tools and instructed on the proper procedure.

Riparian Plant Community Inventory

Plant communities provide most of the components of riparian habitat that are of critical importance to wildlife (Ohmart and Anderson 1986). The vegetation data chosen for study in this inventory are those that will enable future inventories to quantify changes in streamside plant communities. Vegetation response to urbanization in the Rincon Valley will be assessed by measuring changes in 4 parameters: diversity, density, trunk diameter, and percent cover. These parameters were measured for all live woody vegetation (trees and shrubs) and cacti. Future inventories will reveal how the number and distribution of these plant species change with space (between sites) and time (between inventories).

Sample Design for Riparian Plant Community Inventory

The methods used to locate sample plots and inventory riparian plant communities at each study site were based on procedures established by the U.S. Forest Service (Platts et al. 1987) and the U.S. Bureau of Land Management (Myers 1989). Vegetation data were collected by establishing sample plots extending from the transect lines used to collect channel morphology data. Long, rectangular plots were sampled in response to the characteristically riparian shape of the plant communities along Rincon Creek elongated and parallel to the stream channel.

Distinct plant communities and their extent along each transect were identified based on vegetation structural classification parameters (diversity, size, and quantity of vegetation) described by Myers (1989) and Ohmart and Anderson (1988), and landscape features such as terraces. In general, 2 sample plots were established randomly within each plant community encountered along a transect; in the case of extremely narrow communities, 1 plot per transect was sampled.

In order to represent the central tendency of each plant community and minimize influences from adjacent communities, sample plots were situated within homogeneous plant communities, and transitional areas near community borders (ecotones) were avoided (Platts et al. 1987). Five meters was chosen as the minimum distance that plots could be located from community borders; areas dissected by washes or roads were also avoided. Exact plot size and number of plots per transect varied in response to the shape of each plant community, the number of transects at the study site, and other unique site characteristics (see the site descriptions that follow).

At study site A, narrow, short plots (2 m x 20 m) were used in order to sample the 3 narrow communities present and avoid overlapping plots on the site's 5 transects. Due to a property line that prohibited access on the north bank of Rincon Creek, plant community 3 was only wide enough for 1 sample plot on 4 of the 5 transects (Figs. 5 and 6).

Study site B is characterized by 1 large plant community dissected by several small washes. Due to the influence of these washes, density and diversity of plants varied within the community; 15 plots (4 m x 30 m or 4 m x 40 m, depending on the proximity of washes and distance between transects) were therefore sampled to collect data representative of the overall community (Figs. 7 and 8). Areas heavily influenced by washes were not sampled.

At study site C, there is 1 plant community along the south bank and a second community along the north bank. Depending on community width at each transect line, 1 or two 2 m x 40 m plots were sampled in each community along each transect (Figs. 9 and 10).

Only 1 plant community is present along Rincon Creek at study site D. Three 2 m x 40 m plots were sampled along each transect, located randomly in the plant community between the multiple channels of this braided reach (Figs. 11 and 12).

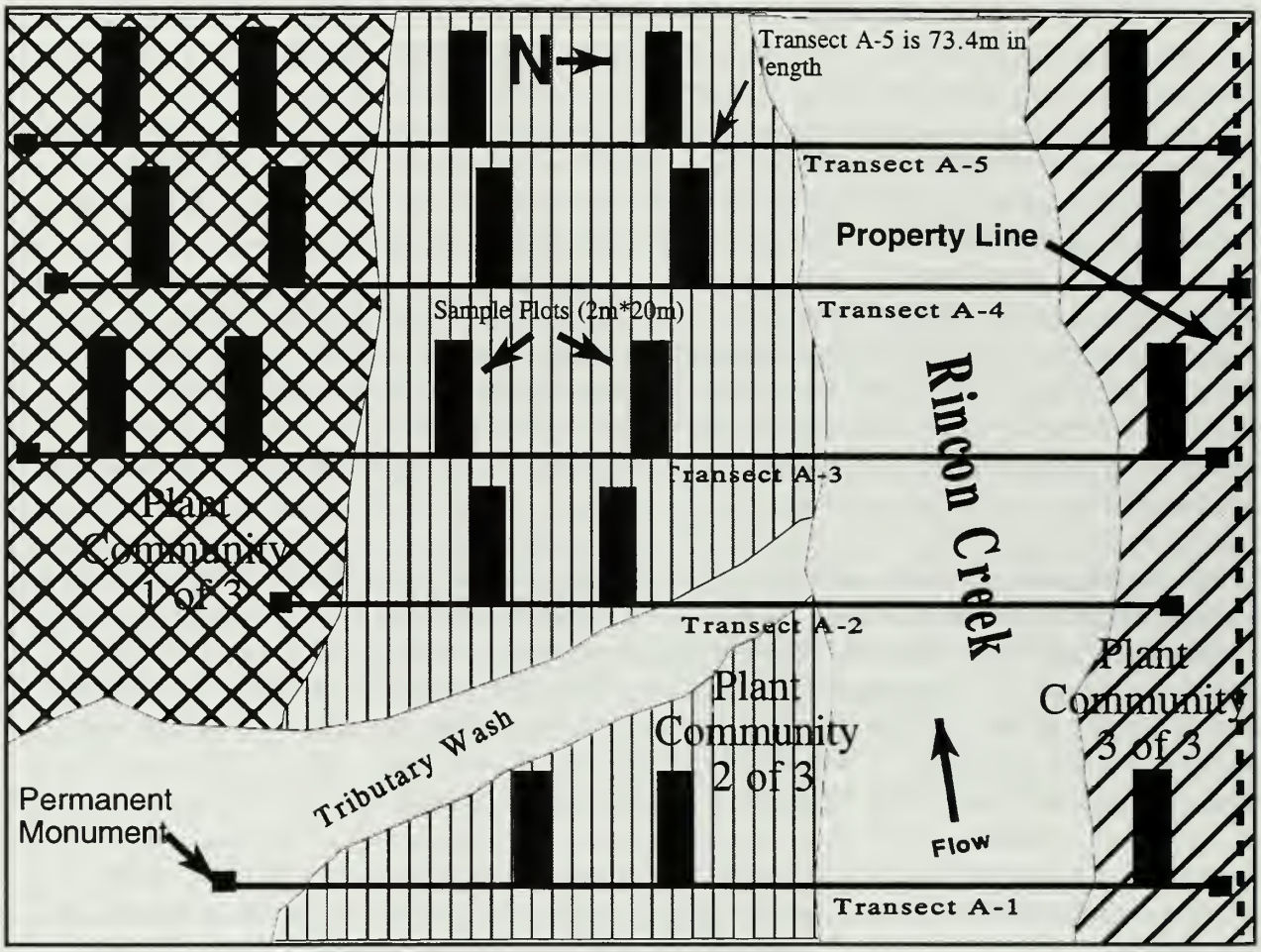

Figure 5. Location of plant communities, sample plots, transects, and permanent monuments in relation to the Rincon Creek channel at study site A. The length of transect A-5 is provided for scale.

Figure 6. Looking south across Rincon Creek, study site A. Stream banks show damage from flood events that occurred during 1993 and 1994.

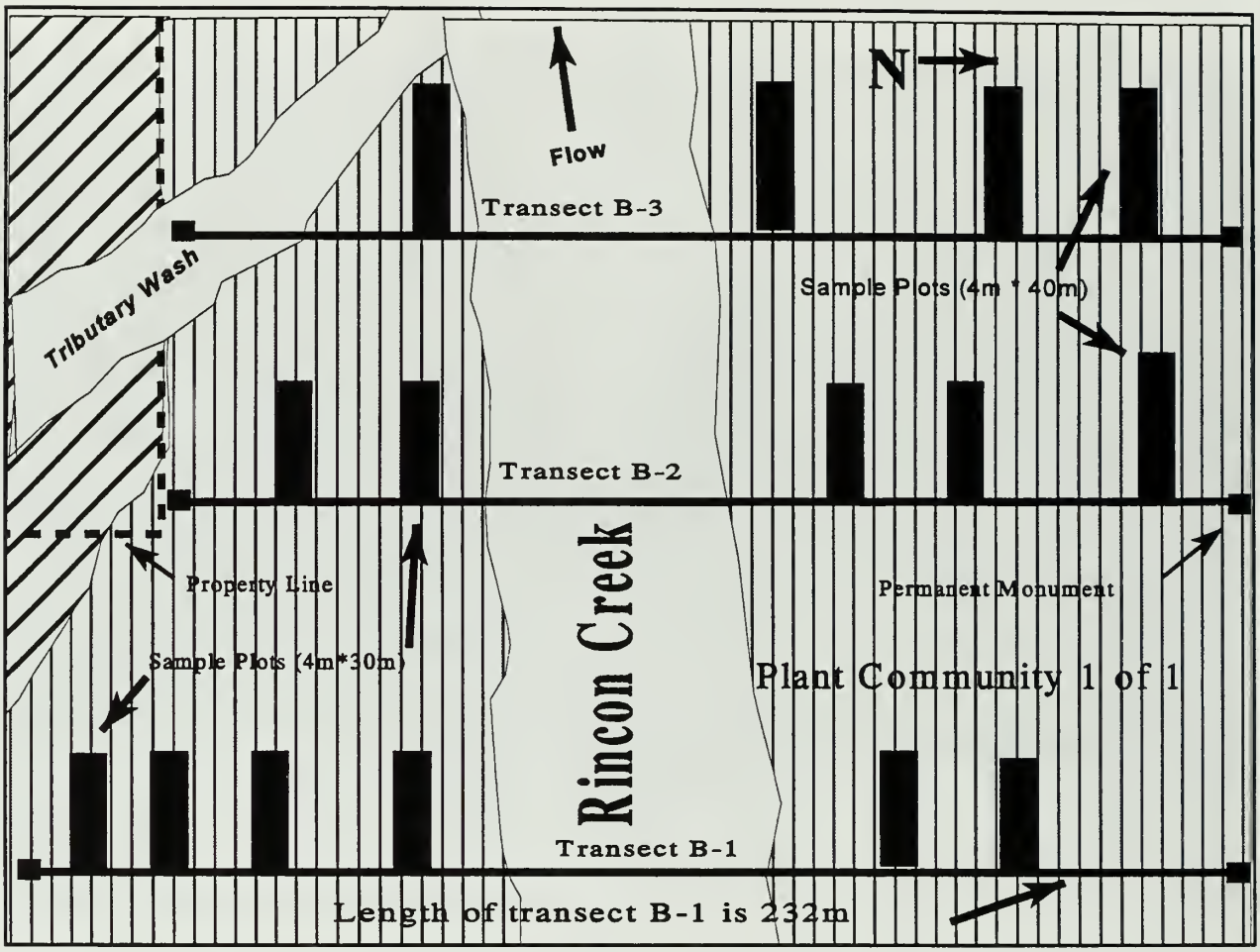

Figure 7. Location of plant communities, sample plots, transects, and permanent monuments in relation to the Rincon Creek channel at study site B. The length of transect B-1 is provided for scale.

Figure 8. Looking upstream at Rincon Creek, study site B. Rincon Peak is in the background.

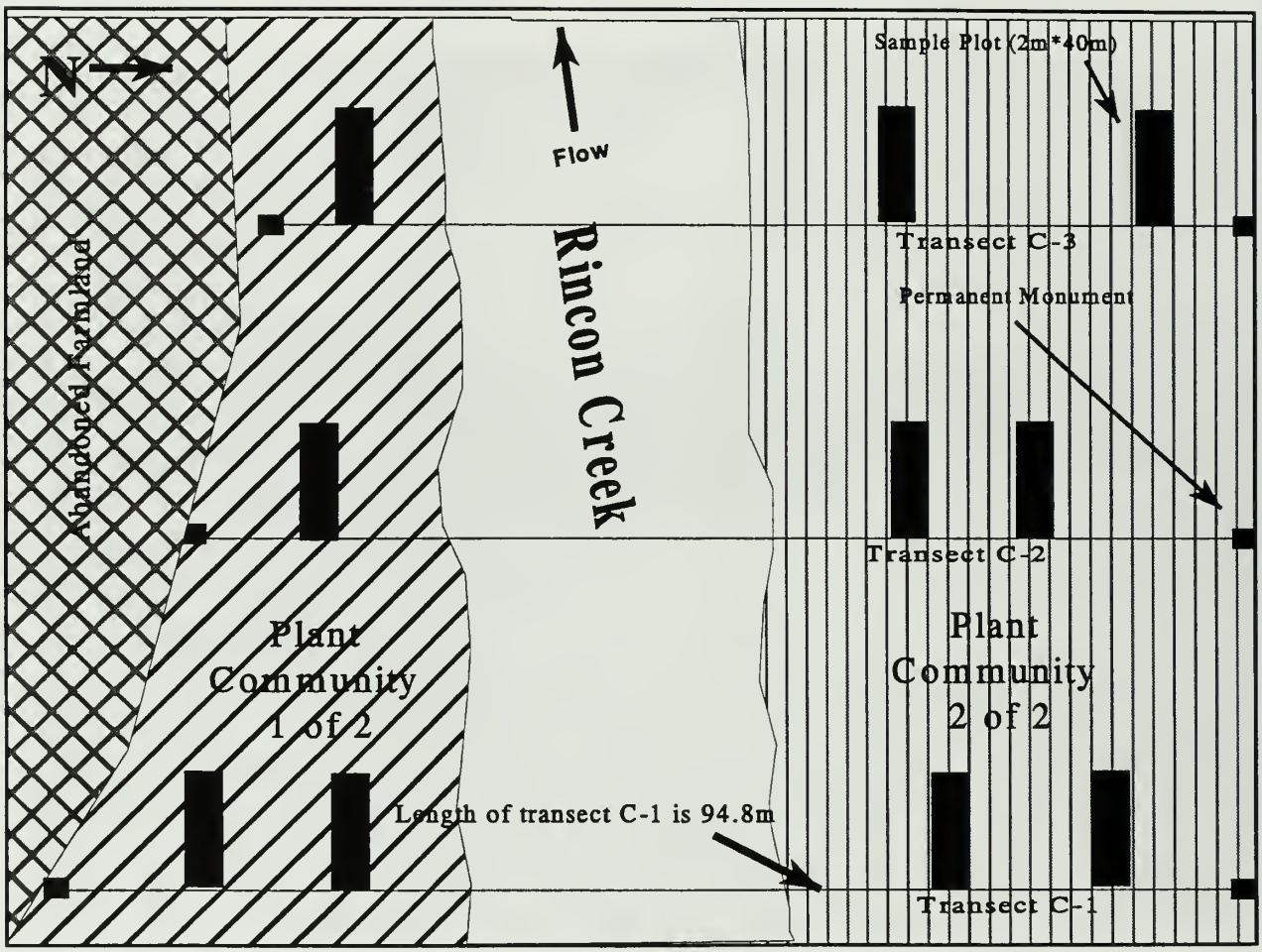

Figure 9. Location of plant communities, sample plots, permanent monuments, and transects in relation to Rincon Creek channel at study site C. The length of transect C-1 is provided for scale.

Figure 10. Looking downstream at study site C. This reach of Rincon Creek has been channelized. In-channel vegetation is dominated by *Hymenoclea monogyra*.

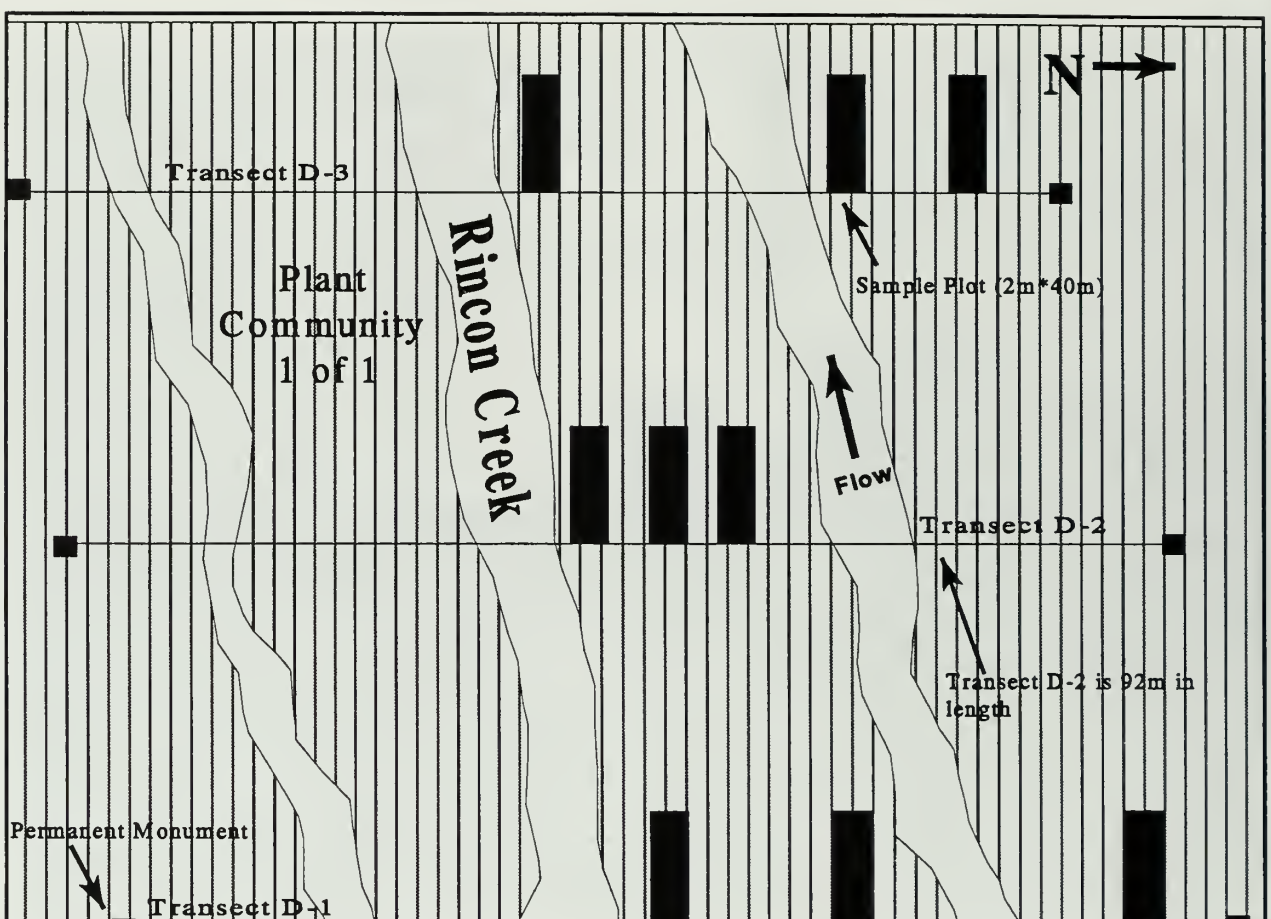

Figure 11. Location of plant communities, sample plots, transects, and permanent monuments in relation to braided Rincon Creek channel at study site D. The length of transect D-3 is provided for scale.

Figure 12. Looking downstream at study site D. *Prosopis velutina* is the dominant overstory vegetation species.

Collecting Data on Riparian Plant Communities

Each sample plot was marked for data collection by running a tape measure perpendicular to the transect line in a downstream direction to delineate the left side of the plot (when looking downstream). For 4 m-wide plots, the tape measure (or a rope) was continued around the perimeter of the plot. For 2 m-wide plots, a 2-m measuring stick carried by the investigator was used to delineate the right side of the plot. Vegetation data were collected during late spring to early summer; future surveys will be performed during the same time of the year. Figure 9 illustrates the general sample design used to collect density, diversity, and trunk diameter data within sample plots, and percent cover data along sample lines.

Population density provides an estimate of the abundance of a particular plant species as the number of individual organisms per unit area (Whittaker 1975; Allaby 1994). To measure the density of each species in the various plant communities at the 4 study sites, all live, woody plants and cacti rooted within the sample plots were counted and recorded by species. If a plot line intercepted any portion of the base of a plant, the plant was considered to be within the plot. For shrub species growing in multi-stemmed clumps, each distinct clump was counted as 1 individual.

Species diversity, or richness, is an index of the number of species in a defined area, and provides an indication of the relative stability and habitat quality of a plant community (Walker 1989). In general, the higher the diversity of the plant species in an ecosystem, the more stable the system. Highly diverse plant communities also generally provide high quality habitat for wildlife, and are positively correlated to wildlife species diversity (Ohmart and Anderson 1988; Anderson and Ohmart 1993). Measurement of diversity for this inventory required a list of all species present in each plant community, and was therefore developed from the density data.

Determining the trunk diameters of the individuals in a plant community provides information on the size distribution of the species present, which gives an indication of age distribution, an important indicator of community vigor and habitat quality (Myers 1989). For example, a predominance of young plants may mean the community is invading the site or recovering from a major environmental disturbance such as fire, while a predominance of older plants may mean grazing or another perturbation is preventing regeneration. Presence of plants from all age classes generally denotes a self-maintaining, climax community (Whittaker 1975; Barbour et al. 1980). The trunk diameters of all live, woody plants were measured in each sample plot. Due to the tendency of many riparian tree species to branch at or near ground level, measurements were taken at the widest section of trunk below the branching point, rather than at breast height. For shrub species growing in multi-stemmed clumps, mean stem diameter was recorded. Diameters were broken into 13 class sizes: 5 cm or less, 5.1–10 cm, 10.1–15 cm, 15.1–20 cm, 20.1–25 cm, 25.1–30 cm, 30.1–35 cm, 35.1–40 cm, 40.1–45 cm, 45.1–50 cm, 50.1–55 cm, 55.1–60 cm, and 60.1 cm or greater.

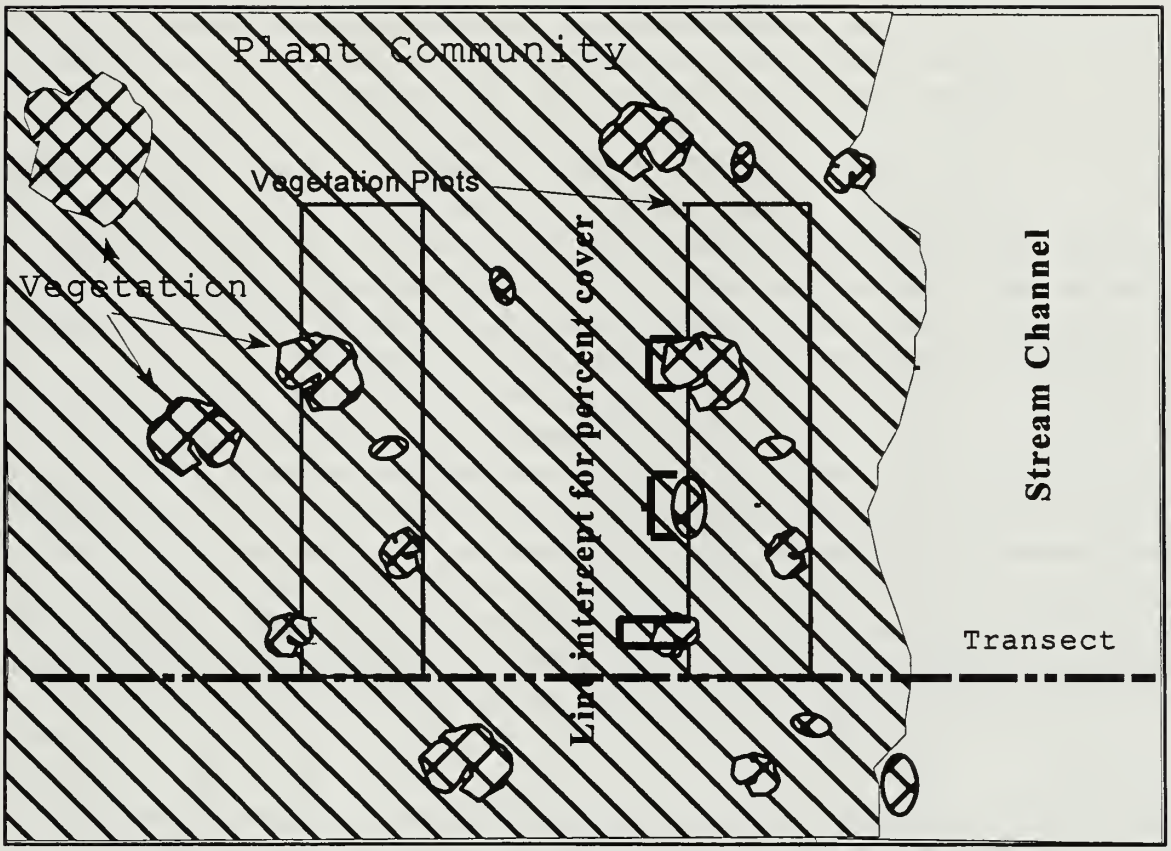

Figure 13. Idealized overview of sample plots for measuring density, diversity, and trunk diameter within a plant community, and the line intercept method for determining percent cover.

For cactus species, trunk diameter was noted but not evaluated because many cacti do not have distinct trunks (e.g., *Opuntia engelmannii*). In addition, this parameter is not as indicative of the age of a cactus as it is of a tree, due to the their different modes of growth.

Cover describes the proportion of ground surface (usually expressed as a percentage) over which live foliage of a species occurs (Whittaker 1975; Allaby 1994). This parameter is an indicator of the size of individuals in a community, which reflects and influences many important riparian site characteristics, functions, and values, including wildlife cover, successional stage, vegetation vigor, thermoregulation, site stability/vulnerability, and many others (Myers 1989). For example, cover is strongly correlated to bird species diversity (Whittaker 1975).

Percent cover was determined using the line intercept method, based on the procedure for estimating proportion of plant cover along taped transects described in Avery (1975) and Gordon et al. (1992). For each sample plot, a 40-m tape was extended perpendicular to the transect line along the left side of the plot when looking downstream (except at study site A, where transect spacing necessitated 20-m lines). The length of sample line intercepted by the aerial foliage of live woody plants and cacti was measured (Fig. 13). Percent cover was calculated for all species encountered: the total length of the sample line intercepted by each species was divided by total line length (20 m for site A) and multiplied by 100.

Photo Points

Photographs taken from identified locations are extremely valuable in a long-term monitoring program. They provide a unique, detailed record of the past and are especially helpful for relocating specific sites. Photographs can be included in GIS and may become even more valuable in the future as technology advances allow additional information to be extracted. The photographs taken during this initial inventory will be compared with photographs taken during future inventories to document and evaluate changes in the habitat along Rincon Creek, whether due to natural causes or management efforts.

Sites for photo points were selected with input from the entire project team, and photographs were taken based on procedures outlined in Harrelson et al. (1994). Photo points were established at each of the 4 study sites and at 3 protected areas (i.e., areas where human modifications are unlikely) that offer an overview of Rincon Creek (Fig. 2). At the 3 overview photo points, several photographs were taken to obtain a panoramic view of that section of Rincon Creek. At each of the 4 study sites, photos were taken looking upstream, downstream, and across the channel from the center transect. Additional photos were taken of each transect line and, where possible, of each study site from a location above the creek.

Photographs were taken during both winter and late spring; repeat photographs will be taken during the same times of the year in future inventories. Since some overstory bottomland species are deciduous, winter photographs may provide more detail of Rincon Creek's physical characteristics than those taken in late spring. Conversely, spring photographs may offer greater biotic detail than those taken in the winter.

Geographical Information System Database

In a project such as this, where a large amount of data was collected, it is important to focus on data management (how the data will be analyzed and the ease with which information can be retrieved). To resolve this issue, a GIS database was created that incorporated topographical, riparian plant community, hydrologic, stream morphology, and land use data.

The data included in the GIS database came from a variety of sources, including historical accounts (interviews with long-term valley residents, ground and aerial photographs, and written documentation); private and public well records; U.S. Geological Survey stream gauge records; and this inventory. The objective of this database is to provide a chronological view of channel morphology, riparian vegetation, and stream hydrology changes since the mid-1930s relative to land use changes in the Rincon Creek watershed.

Intergraph

Selected reaches were mapped and data entered into Intergraph's MGE GIS. The database was designed so that information could be easily converted and attributed in Arc Info format. Three kinds of GIS formats were used in this study: vector, topology, and raster. Vegetation and land use data were mapped in vector format to maintain the original integrity of the data. Topological data structure was used to construct hydrologic features. Topology is a kind of geometry that assists the user in redefining elements in terms of their interrelationships with contiguous elements.

Topology was used to record the spatial relationships that exist among specific geographic data, such as the sections of the stream corridor and coinciding data, and used with new data collected to analyze changes in stream morphology. All data were converted to raster for input into the dynamic model. This GIS structure is comprised of the following basic information:

Topography
Vegetation
Hydrologic features (channel and floodplain)
Land use

Both spatial and attribute base query capabilities can be performed on the data in addition to the requirements of the dynamic model.

Database Construction

Oracle, a relational database, was constructed for the study reach of Rincon Creek. This database contains information describing channel gradient, sinuosity, width/depth ratio, entrenchment of channel and confinement of channel in valley, land-form features, stream size, etc. This information will be collected over a number of years, entered into the database and used to illustrate changes.

Dynamic Feature Change Analysis

Aside from creating a database of the Rincon Creek watershed, the purpose of this study is to examine and map morphological changes to the creek over time. This was achieved in 2 ways. First, by using geo-referenced aerial photographs from historic time periods, changes to Rincon Creek morphology were analyzed and mapped. This provided a map layer of degree of physical change, but did not necessarily indicate what important factors can be used to predict change.

Second, to determine what factors more strongly influence the degree of change, a program was developed to collect data and monitor activities along the stream over many years. These data will continue to be entered into a database and used to more accurately depict changes. This will be accomplished through the use of Intergraph's Dynamo software using a technique referred to as dynamic segmentation. Using this technique, any change in the existing pattern of stream morphology or shape can be automatically recalculated and reflected in the database. These changes will then assist in identifying and predicting long-term impacts on the hydrologic system.

Riparian Environment Simulation Model Development

While GIS technology provides powerful programs for storing and retrieving spatially referenced data, interest has been expressed in using GIS for simulation of spatial dynamic ecological processes. Conventional GIS systems do not include procedures for handling time, are designed to process entire arrays of data, and cannot easily address varying localized operations across the spatial grid. The task of simulation software is to provide the dynamic state projection necessary for understanding complex system behavior and ultimately providing decision support for riparian management. However, state-of-the-art simulation software does not have adequate capability to access the huge volumes of data necessary for realistic landscape representation. Adequate simulation modeling of landscape ecosystem processes require the integration of the 2 technologies, GIS and simulation, into a new single environment with both database and simulation strengths.

Recent research has demonstrated how a DEVS (Discrete Event System Specification) formalism for cellular spaces and a GIS database can be interfaced to provide ecosystem simulations of fire spread and forest succession not possible before. This is accomplished using discrete-event, object-oriented simulation of hierarchical modular models.

For this project, we developed a model similar to the fire spread model for the riparian environment to demonstrate how it has changed over time since the turn of the century. In addition, with the ongoing collection of data on the riparian environment, the model will be capable of simulating future events and impacts due to land use changes.

A series of simple hierarchical models, representing groundwater, streamflow, sediment movement, and vegetation, was developed under the DEVS formalism to simulate changes over time. Future changes in land use patterns will be communicated to and processed by the DEVS model, and predictions of how they will impact the riparian environment will be made.

Technical Methods of Procedure:

1. Digitized topography from USGS quad sheets.
2. Digitized infrastructure (roads, buildings, etc.) from engineering drawings.
3. Scanned aerial photographs, rectified, and geo-corrected.
4. Mapped vegetation information from aerial photographs (vector).
5. Mapped channel changes from aerial photographs (vector).
6. Developed database structure for on-going monitoring.
7. Attributed vector information to create GIS.
8. Analyzed changes to stream morphology based on historic information.
9. Established guidelines for stream monitoring activities.
10. Established methods for determining changes to stream morphology.
11. Established methods for development and linkage of hierarchical models.

Results and Discussion

Channel Morphology and Riparian Plant Communities

Study Site A

The cross-sectional profile of the Rincon Creek channel at study site A reveals the channel morphology typical of a riparian stream in the desert Southwest, with a well-defined active stream channel and clearly delineated terraces (Fig. 14). The channel is 33 m wide at bankfull width; elevation along the channel cross section ranges from 926.3–927.3 m, with 2 low-flow channels straddling a wide depositional feature, and terraces beginning at approximately 928.5 m in elevation. The lower elevational terrace on the south side of the stream is a wide, level floodplain, while the terrace on the north side is quite steep. The upper elevational terrace on the south side rises steadily from 928.8–932 m. The left bank rises 2 m over a distance of 4 m, while the right bank is steeper, rising the same distance in only 5 m. Both banks are devoid of woody vegetation but scattered with forbs and grasses. In-channel vegetation is present, with *Baccharis glutinosa* upstream from the study site A and a large *Platanus wrightii* just downstream.

Plant community A-1 is located on the upper elevational terrace on the south side of Rincon Creek. This terrace is no longer subjected to flood events (Fig. 14).

This plant community is the most diverse, as well as most densely populated and foliated, of the 3 communities at study site A. It is dominated by *Prosopis velutina* and *Acacia greggii*, with *P. velutina* providing by far the most cover (Fig. 15). Scattered throughout is a variety of shrubs and cacti, including *Celtis pallida*, *Isocoma tenuisecta*, *Atriplex canescens*, *Opuntia versicolor*, *Echinocereus engelmannii*, *Ferocactus wislizenii*, *Opuntia engelmannii,* and *Ziziphus obtusifolia.*

The density of *P. velutina* in plant community A-1 is 1,750/ha, and *P. velutina* provides most of the cover in the community, with a total percent cover of 50.8%. Although the density of *Acacia greggii* is 1,292/ha, it covers a total of only 6% of the ground. *Celtis pallida* also provides a small amount of cover (3%). The desert shrubs *Isocoma tenuisecta* and *Ziziphus obtusifolia* provide minimal cover (1.4% and 0.8% respectively). Of the various cactus species present, *Opuntia versicolor* is the most abundant (with a density of 125/ha) and was the only cactus that intercepted sample intercept lines, yielding a total percent cover of 0.1%.

Both dominant tree populations in plant community A-1 are composed primarily of small, young individuals, with well over half of the trees sampled having diameters of $\leq$ 5 cm. However, while all *Acacia* spp. trunk diameters are small (ranging from 2.5–8.9 cm), 4 out of the 42 *Prosopis velutina* present in sample plots have trunks measuring 12.7 cm. This explains *Acacia* spp. relatively lower total percent cover. Trunk diameter breakdowns are not shown for the shrubs present because they are multi-stemmed, with stem diameters not exceeding 5 cm.

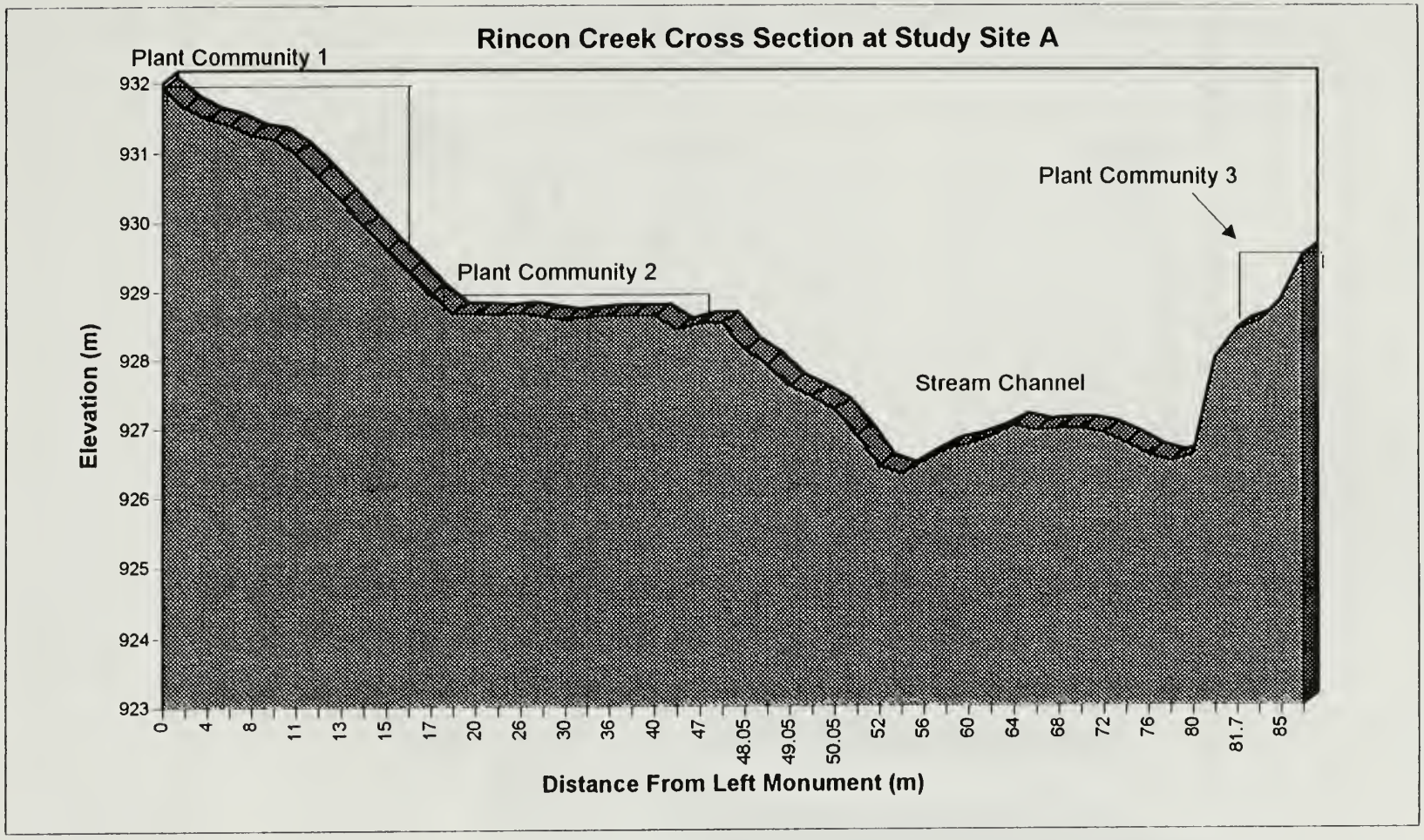

Figure 14. Cross-sectional profile of Rincon Creek at study site A.

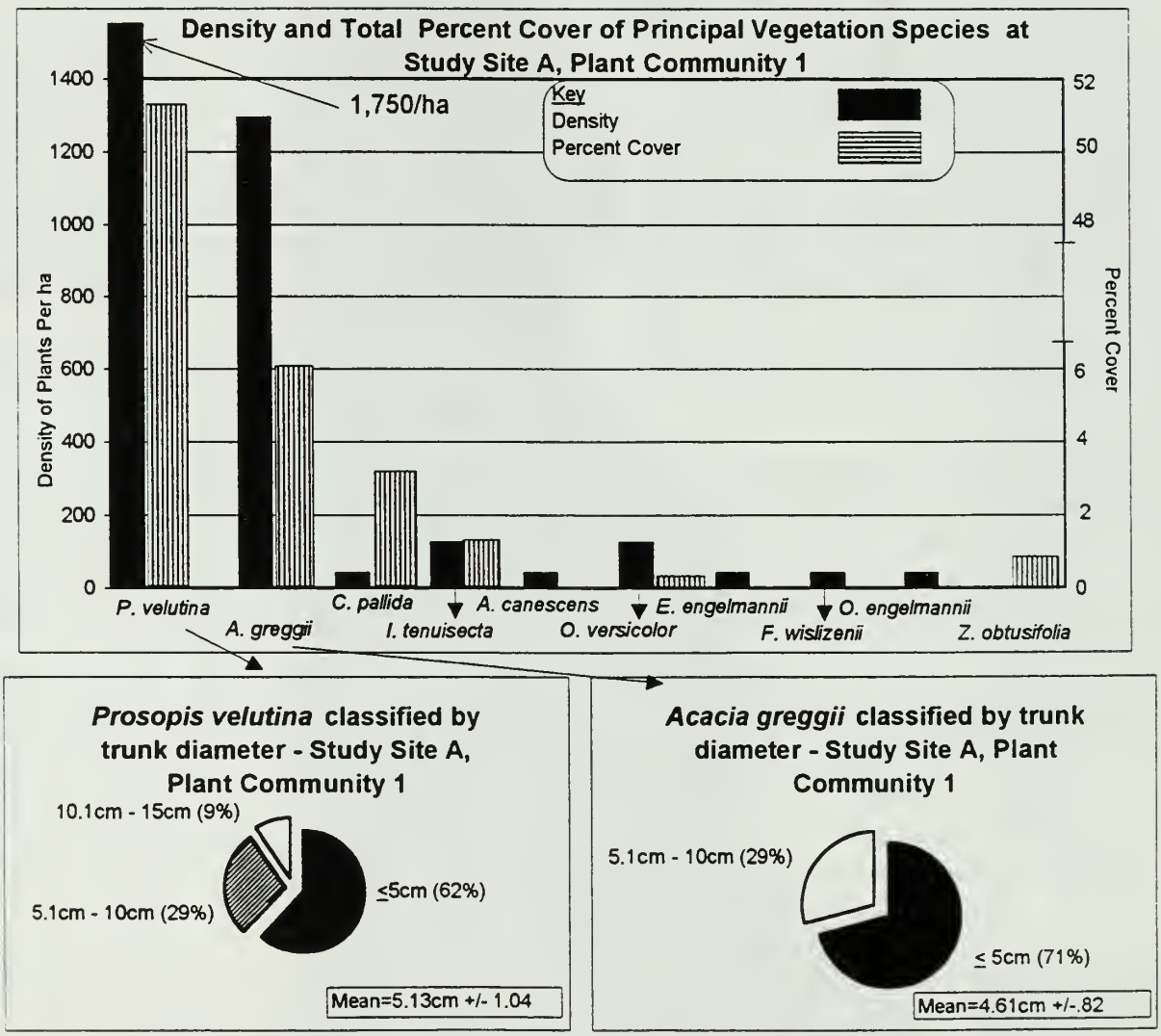

Figure 15. Summary of vegetation data collected at Rincon Creek study site A, plant community 1

Plant community A-2 is located on a wide, level terrace within the active floodplain on the south side of Rincon Creek at an elevation of 928.5 m, and is infrequently subjected to flood events at intervals of 5–10 years (Fig. 14).

This community is the most sparsely populated of the 3 communities at study site A, and is quite open (Fig. 16). Species diversity is also fairly low. The community is dominated by several characteristic riparian trees: *Celtis reticulata*, *Fraxinus velutina*, and *Prosopis velutina*. *Baccharis sarothroides* is also numerous but, due to its spindly form, provides little cover. *Acacia greggii* is present to a lesser extent.

C. reticulata is the most abundant of the dominant species in plant community A-2, and provides the most cover. The density of *C. reticulata* is 450/ha, while total percent cover is 29.9%. The density of *P. velutina* is 225/ha, while the density of *F. velutina* is 75/ha. Although *F. velutina* is not as numerous as *P. velutina*, the 2 species cover essentially the same percentage of ground within the community (13.5 and 16.4% respectively). On the other hand, although *A. greggii* and *F. velutina* have the same density (75/ha), *Acacia* spp. provides a total of only 3.3% cover. At 250/ha, the density of *B. sarothroides* is similar to that of *P. velutina*; however, its total percent cover is only 4.5%.

The *C. reticulata* population exhibits the widest size and age distribution of the dominant species in plant community A-2, with trunk diameters ranging from < 5–24.1 cm. Most of these trees are mature: 50% of them have trunk diameters of between 15.1 and 20 cm. All *F. velutina* trees sampled are approximately the same age, with trunk diameters between 16.5 and 19 cm. The *P. velutina* population exhibits an even spread of trunk diameters ranging from 7.6–19 cm. The smaller *A. greggii* population is also evenly spread, with trunk diameters ranging from 7.6–16.5 cm. As the many stems of a *B. sarothroides* shrub do not grow much beyond 5 cm in diameter, a breakdown of trunk diameter for this species is not shown.

Plant community A-3 (Fig. 17) is located on a narrow, sloping terrace within the active floodplain on the north side of Rincon Creek, and is infrequently subjected to flood events at intervals of once every 5–10 years. The elevation of the terrace ranges from 928–929.5 m (Fig. 14).

This community is quite sparsely populated and has the least amount of cover-providing foliage of the 3 communities at study site A (Fig 13). Species diversity is the lowest of all sites sampled, with only 4 woody plant species present. The community is composed of characteristic riparian trees: *Prosopis velutina*, *Acacia greggii*, *Celtis reticulata*, and *Fraxinus velutina*. *Ferocactus wislizenii* is scattered throughout, and 1 *Opuntia engelmannii* was sampled.

Although *A. greggii* exhibits the highest density (687.5/ha) of the 4 tree species in plant community A-3, it provides essentially the same amount of cover as do *P. velutina*, *C. reticulata* and *F. velutina*: total percent cover is 12.4% for *Acacia*, while it is 15.4% for *P. velutina*, and 13.6% for both *C. reticulata* and *F. velutina*. *F. velutina* provides that much cover despite having the lowest density (62.5/ha). While *P. velutina* provides the highest amount of cover, its density is only 125/ha. *Celtis pallida* and *F. wislizenii* both have a density of 312.5/ha.

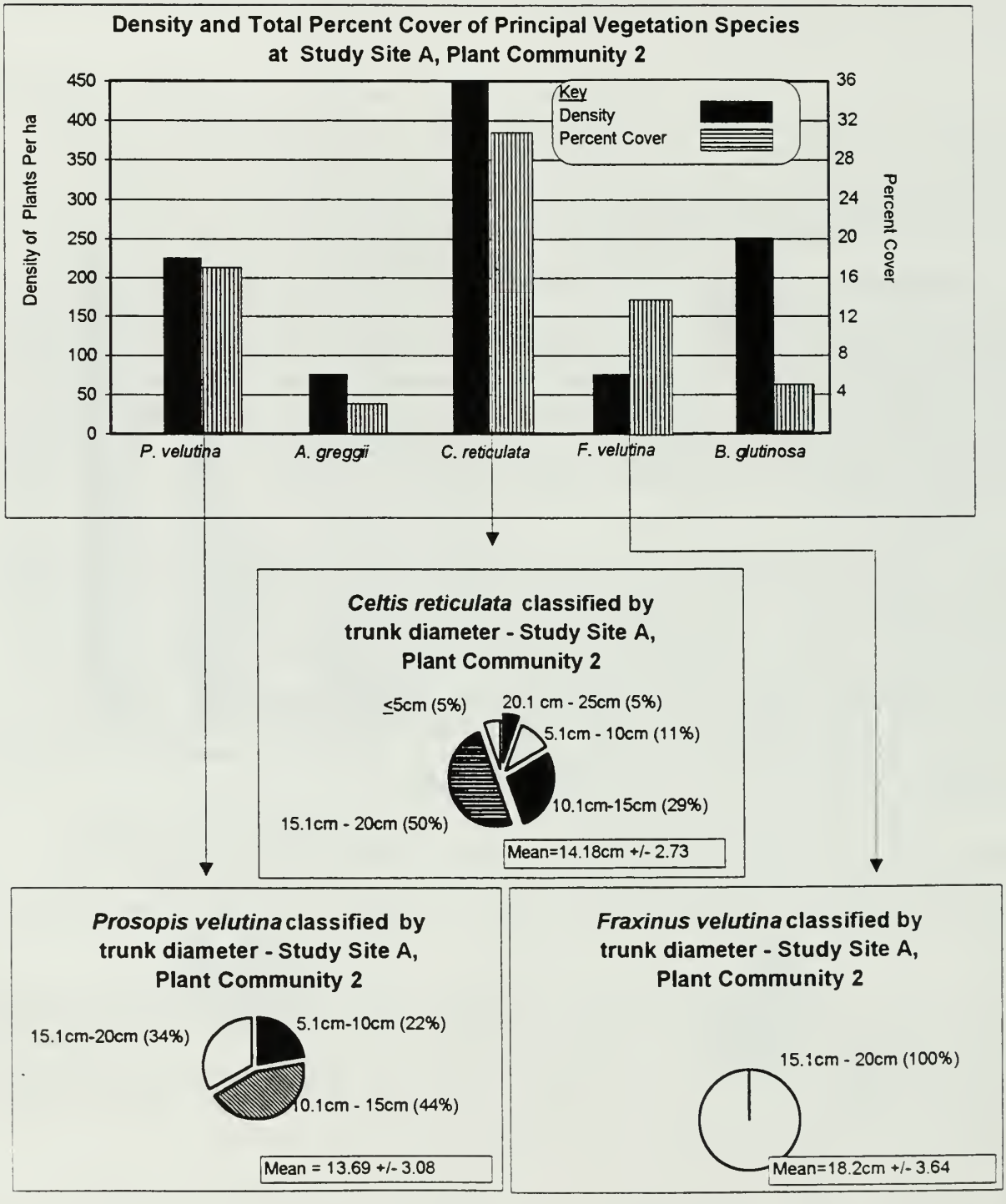

Figure 16. Summary of vegetation data collected at Rincon Creek study site A, plant community 2

The few *P. velutina* present are large, mature plants with trunk diameters ranging from 11.4–22.9 cm. The single *F. velutina* sampled is also mature (with a trunk diameter of 17.8 cm), explaining the relatively high amount of cover it provides. The same is true of *C. reticulata*, whose trunk diameters range from 8.9–20.3 cm. The *A. greggii* population is primarily composed of young plants with trunk diameters ranging from 2.5–8.9 cm.

Study Site B

The cross-sectional profile of the Rincon Creek channel at study site B reflects the channelization of this reach that was carried out in recent decades to protect nearby ranch houses from flooding (Fig. 18). The channel here is narrower than at study site A (33 m bankfull width) and both banks are steep, each rising approximately 1.8 m over a distance of 4 m. Channel elevation is approximately 914.25 m, with a level terrace on both sides at an elevation of just over 915.5 m. The terraces are incised by several small washes. Very little in-channel vegetation is present (only a few spindly *Hymenoclea monogyra*).

Only 1 large plant community is present at study site B. The site is situated within the active floodplain on both sides of the creek at elevations ranging from 914.3–916.5 m (Fig. 18). This community is dissected by several small washes; however, because Rincon Creek has been channelized along this reach, the community is infrequently subjected to flood events (at intervals of 5–10 years).

Plant community B is a dense mesquite bosque, with *Lycium pallidum* and *Atriplex canescens* dominating in the understory (Fig. 19). *Celtis reticulata* is occasionally co-dominant. Other riparian trees including *Acacia greggii*, *Fraxinus velutina*, *Chilopsis linearis,* and *Anisacanthus thurberi* are scattered here and there, as are other shrubs including *Hymenoclea monogyra* and *Ziziphus obtusifolia*. Diversity is lower in plots influenced by frequent flow through nearby washes, and higher in less disturbed areas (areas heavily influenced by a wash were not sampled).

P. velutina was present in every sample plot and along every sample intercept line at study site B. Density of *P. velutina* is 1,180/ha, and the total percentage of ground covered by *P. velutina* foliage is 50.8%. *L. pallidum* and *A. canescens* have similar densities (365/ha and 275/ha respectively), and provide a similar amount of cover (7.3 and 2.6% respectively). *L. pallidum* shrubs were absent in only 2 out of the 15 sample plots. *C. reticulata* trees were scattered throughout the sample plots, and a healthy stand of this characteristic riparian species was sampled in 1 plot. In spite of its fairly low density (115/ha), *C. reticulata* provides a total of 12.6% cover, second only to *P. velutina*.

The wide range in *P. velutina* trunk diameters (ranging from 2.5–49.5 cm) indicates a healthy, mixed-age stand. The same is true for the *C. reticulata* population, whose trunks range in diameter from 3.8–37.5 cm. Well over half of the *A. greggii* population is made up of small, young plants ranging from 0.6–5.7 cm. One unusually large, old *Acacia* (with a trunk diameter of 34 cm) was sampled in the community. As all *L. pallidum* shrubs present are young with multiple stems all < 5 cm, and the many stems of *A. canescens* do not grow beyond 5 cm in diameter, breakdowns of trunk diameter for these species are not shown.

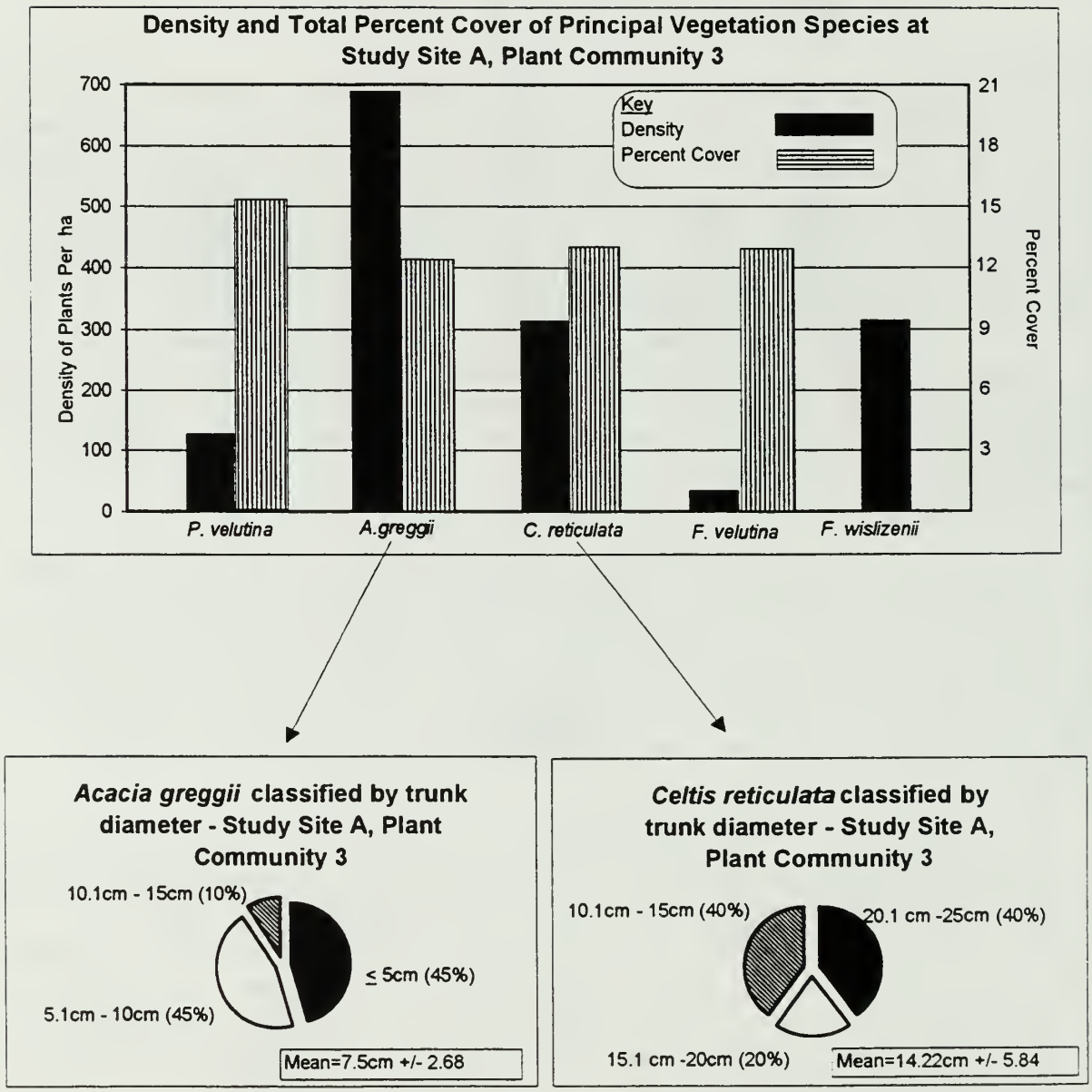

Figure 17. Summary of vegetation data collected at Rincon Creek study site A, plant community 3.

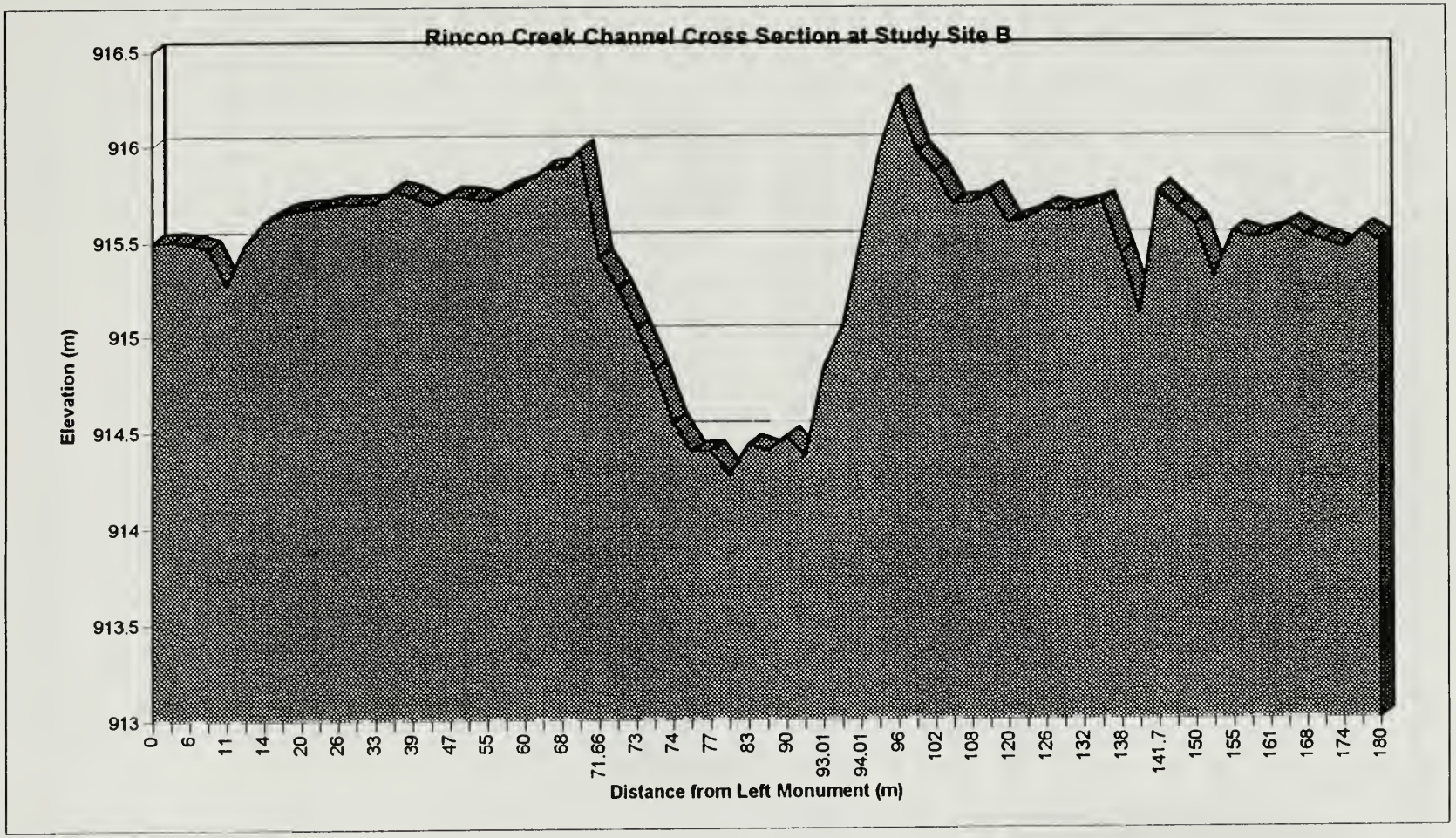

Figure 18. Cross-sectional profile of Rincon Creek channel at study site B.

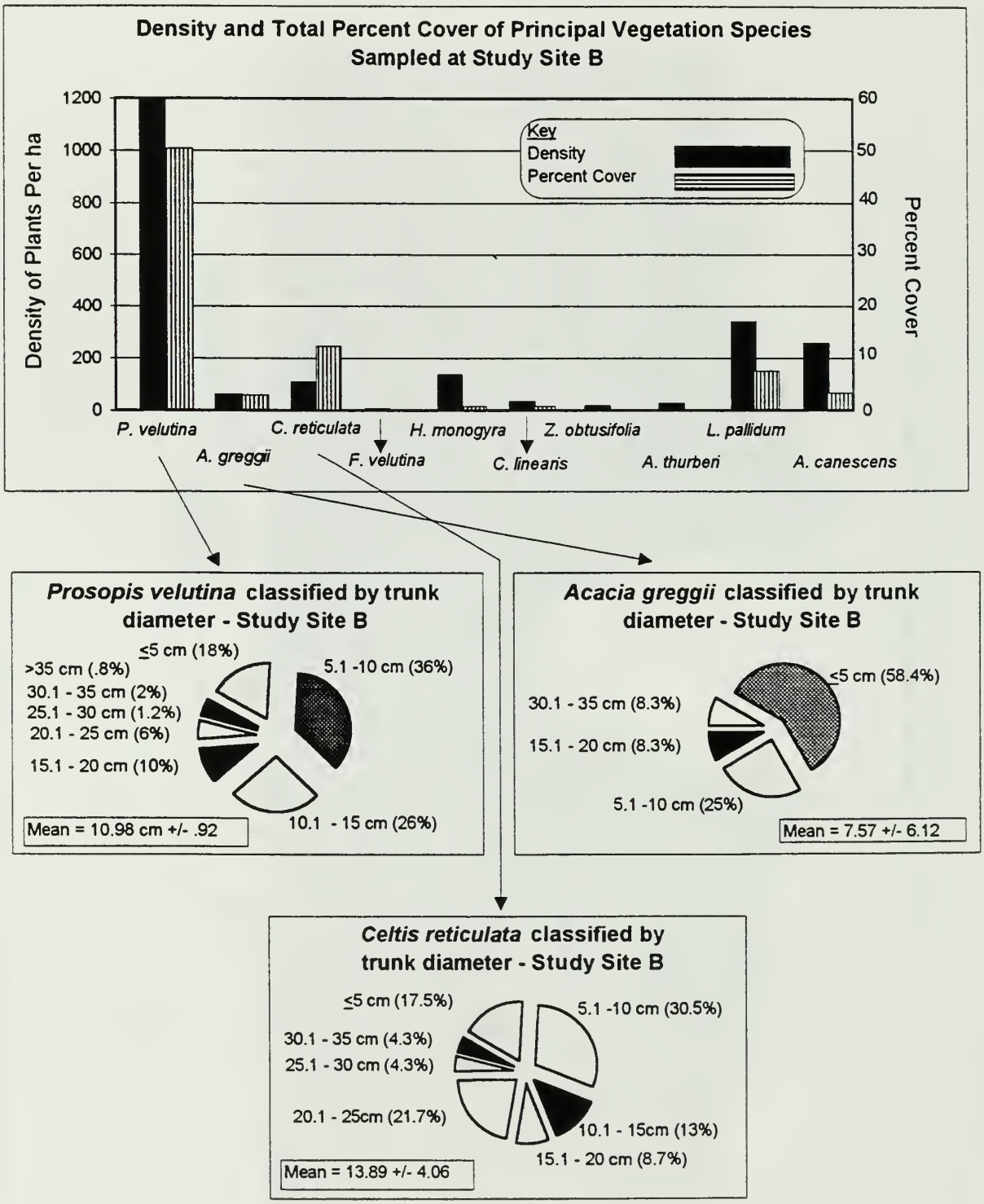

Figure 19. Summary of vegetation data collected at Rincon Creek study site B.

Study Site C

The channel morphology of study site C exhibits the extreme channelization of this reach of Rincon Creek that was carried out in the 1950s in an attempt to protect adjacent agricultural fields from flooding (Fig. 20). Massive earthen berms on both sides of the creek rise 2.5 m above the channel bed, which at this site lies at an elevation of approximately 890.25 m. The channel is approximately 36 m wide at "bermfull" width. On the other side of the berms are level terraces that are only slightly higher than the channel bed at an elevation of approximately 891 m. The berms have been breached by floods at several locations, resulting in some incision of the adjacent terraces.

Plant community C-1 is located on abandoned agricultural fields situated on the previously active floodplain along the south side of Rincon Creek (Fig. 20). Although extensive channelization has been performed along this reach of the creek for agricultural purposes, the artificial berms are fairly regularly breached by flood events and the floodplain is inundated every 2 years or so.

This plant community is heavily dominated by 2 shrubs typical of disturbed sites in the desert Southwest: *Hymenoclea monogyra* and *Isocoma tenuisecta* (Fig. 21). *H. monogyra* is by far the most numerous species present. In relation to its extremely high density, this shrub provides scant cover; *I. tenuisecta* provides even less. A few lone *Prosopis velutina*, *Acacia greggii*, *Chilopsis linearis*, *Fraxinus velutina* and *Celtis reticulata* trees are present, as are a few *Baccharis sarothroides,* and *Lycium pallidum* shrubs.

The density of *H. monogyra* in plant community C-1 is extremely high (11,844/ha), while its total percent cover is 26.4%. *I. tenuisecta* density is 250/ha; however, the cover provided by this species is only 0.5%. One large *C. reticulata* was sampled; because of its size, it provides a significant amount of cover (10.7%). The few *A. greggii* and *F. velutina* trees present in the area also provide some spotty cover. Total percent cover is 8.2% for *A. greggii* and 5.1% for *F. velutina*.

Breakdowns of the trunk diameters of the dominant shrubs in plant community C-1 are not presented because their many stems do not grow beyond 5 cm in diameter. The few *P. velutina* and *A. greggii* sampled are young, with trunk diameters ranging from 3.8–6.4 cm. The trunk diameter of the single mature *C. reticulata* sampled is 31.8 cm.

Plant community C-2 is located on the previously active floodplain along the north side of Rincon Creek (Fig. 20). This side of the creek has been less utilized for agricultural purposes than the south side. As with plant community C-1, the artificial berms along the channel are fairly regularly breached by flood events and the floodplain is inundated every couple of years.

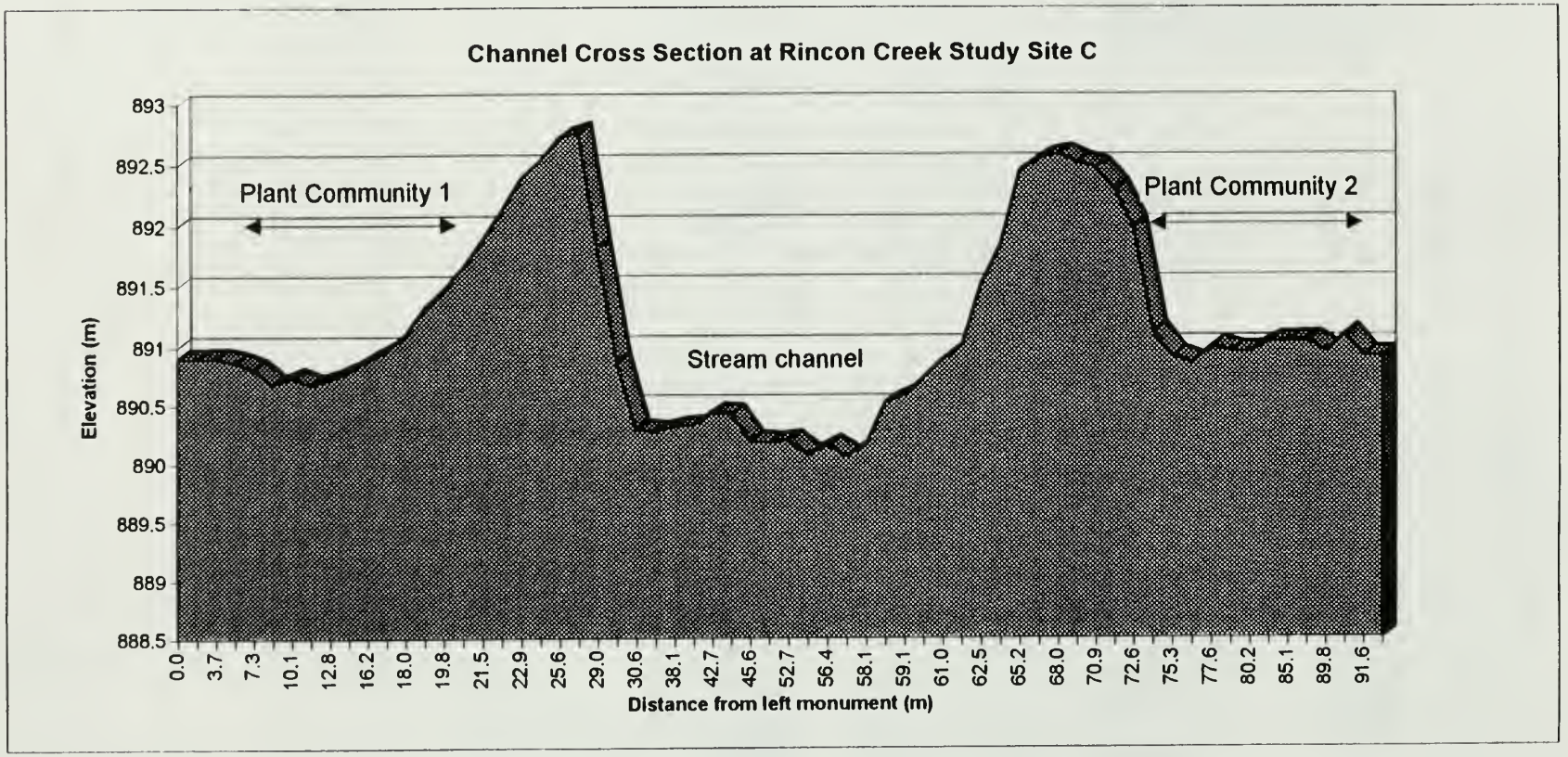

Figure 20. Cross-sectional profile of Rincon Creek at study site C.

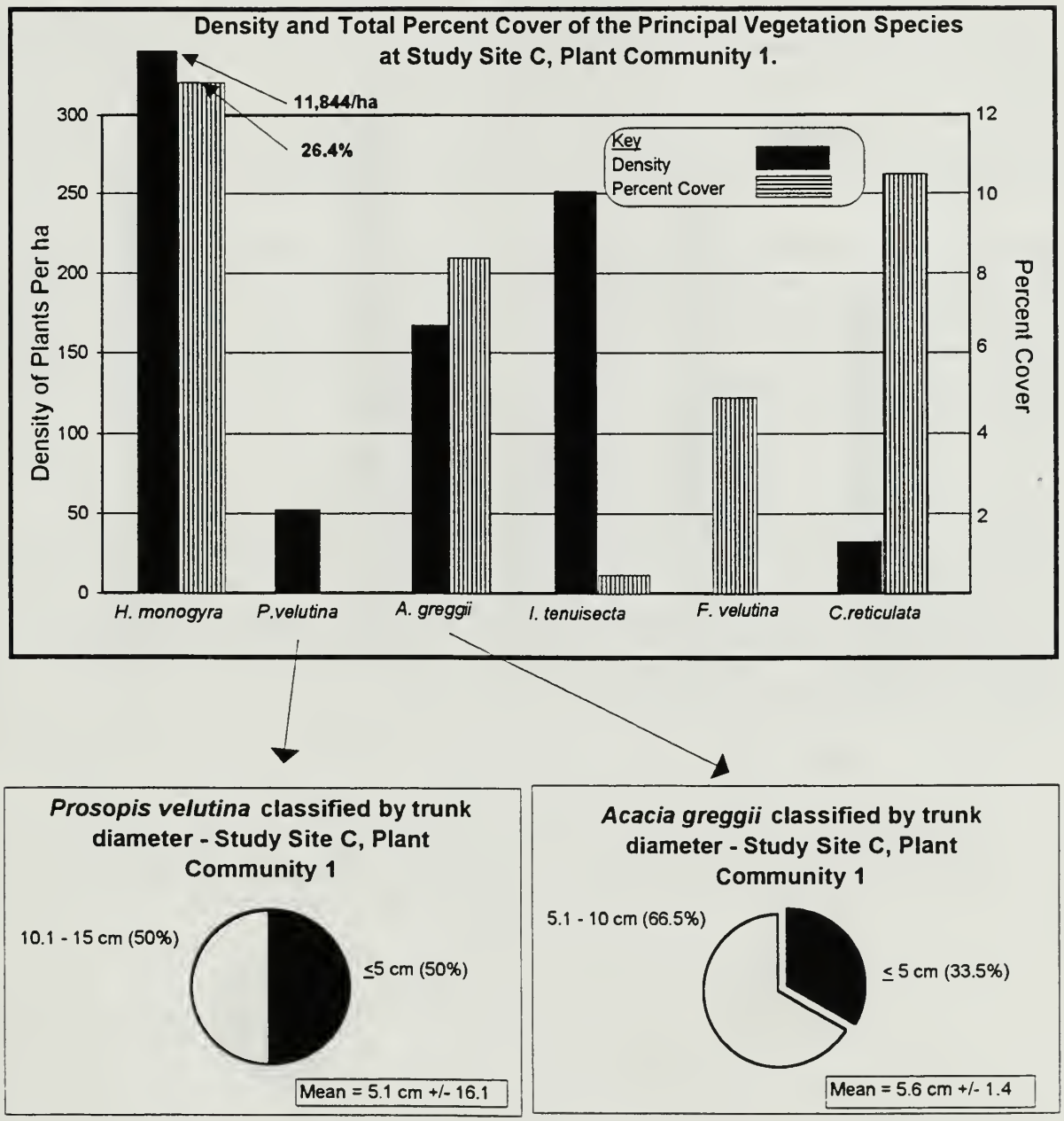

Figure 21. Summary of vegetation data collected at Rincon Creek study site C, plant community 1.

This community, like plant community C-1, is heavily dominated by shrubs that thrive on disturbed sites (Fig. 22). In plant community C-2, *Isocoma tenuisecta* is by far the most abundant species, with *Hymenoclea monogyra* also very common. *Baccharis sarothroides* is quite numerous as well. Due to the prevalence of *I. tenuisecta*, cover is extremely sparse. A few small *Prosopis velutina* trees are evenly scattered throughout the community, and 1 healthy stand of *Chilopsis linearis* was sampled. *Opuntia engelmannii* cacti appear here and there. Even less common are *Celtis reticulata* and *Acacia greggii* trees. One *Ericameria laricifolia*, 1 *Ferocactus wislizenii*, 1 *Opuntia bigelovii*, and 1 *Lycium pallidum* shrub were also sampled, giving this barren, disturbed community the highest diversity of all communities sampled.

The density of *I. tenuisecta* in plant community C-2 is 10,938/ha, while the species provides a total of only 15.7% cover. Although the density of *H. monogyra* is 1,333/ha, it provides only 2.5% total percent cover. The density of *B. sarothroides* is 229/ha; however, the cover provided by this shrub species is only 1.2%. *P. velutina* is present at a density of exactly 125/ha: all plots sampled contained 1 *P. velutina* tree. The 9 *C. linearis* trees that occurred within sample plots yield a density of 187.5/ha.

As in plant community C-1, breakdowns of the trunk diameters of the dominant shrubs in plant community C-2 are not presented because their many stems do not grow beyond 5 cm in diameter. The *C. linearis* population that was sampled contains individuals with a good range of trunk diameters that are fairly evenly spread between large, mature trees and smaller, younger trees (ranging from 3.8–20.3 cm in diameter). The sparse *P. velutina* population is entirely composed of young individuals with trunk diameters ranging from 3.8–7.6 cm; the single *C. reticulata* sampled is also young (trunk diameter 5.1 cm).

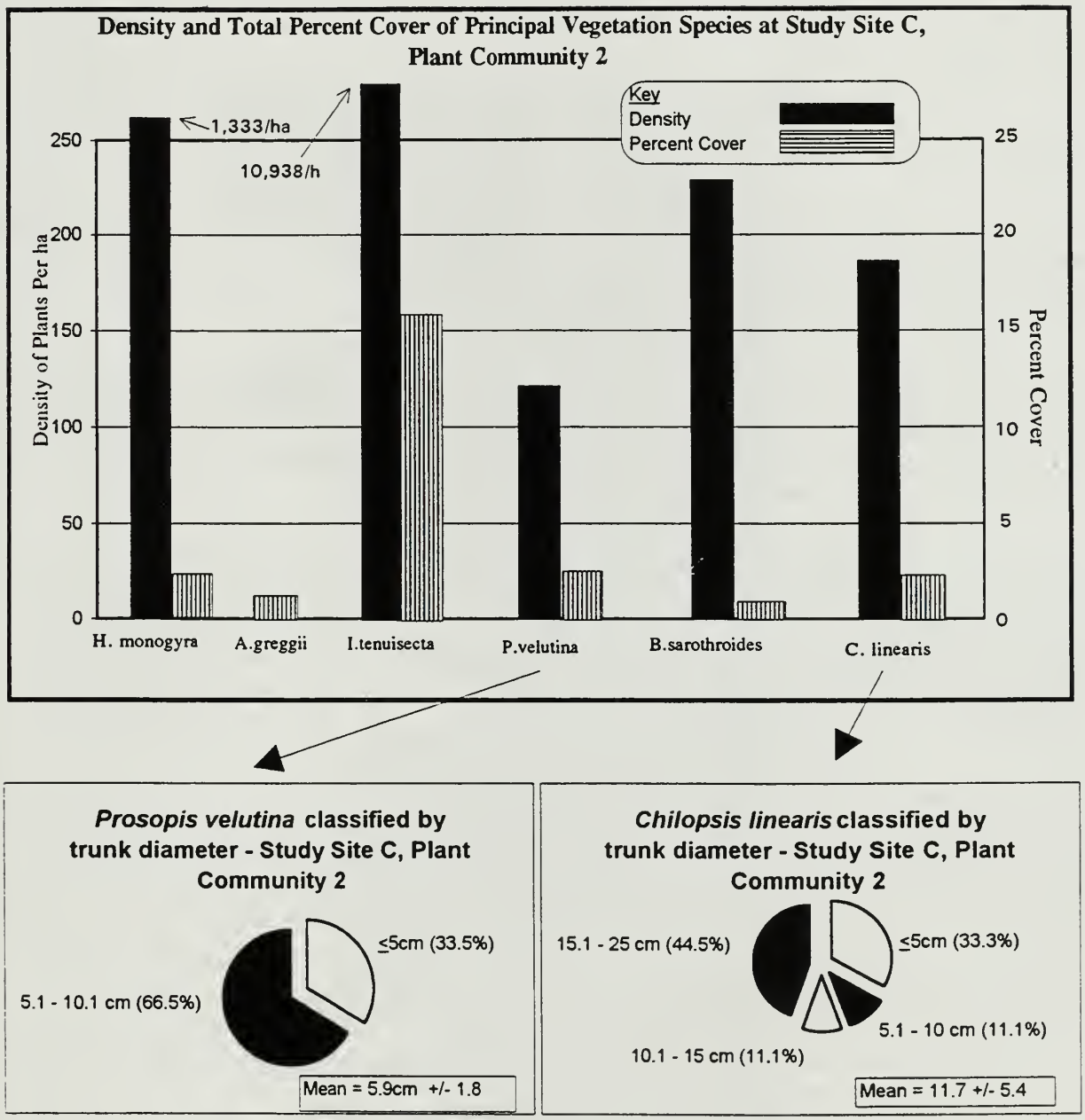

Figure 22. Summary of vegetation data collected at Rincon Creek study site C, plant community 2.

Study Site D

The channel morphology of Rincon Creek at study site D is markedly different than at the other 3 study sites (Fig. 23). This reach is very wide and level, extending from Old Spanish Trail (which lies just beyond the left transect monuments) approximately 90 m to the north. The cross-sectional profile exhibits a braided channel pattern, with the widest channel being just over 6 m wide. There is little elevational difference between the multiple channels and the vegetated islands between them (generally only about 0.5 m). The lowest channel bed is at an elevation of 875.4 m; the highest is at approximately 876 m. The vegetated islands are all at elevations ranging from 876–876.6 m.

Only 1 large plant community is present at study site D. It is situated within the active floodplain of Rincon Creek (Fig. 23). Due to the braided channel pattern at this site, and the very small changes in elevation between the multiple channel beds and the plant community, this community is regularly inundated every year (i.e., whenever the creek flows).

Plant community D is a dense *Prosopis velutina* and *Acacia greggii* bosque, with *P. velutina* providing almost all of the abundant cover (Fig. 24). A few *Celtis pallida*, *Atriplex canescens*, *Hymenoclea monogyra*, and *Lycium pallidum* are scattered here and there. *Chilopsis linearis* was found along 1 sample intercept line.

The density of *P. velutina* in this community is 736/ha. These trees provide a total of 78.2% cover, the highest of any plant community sampled. Although the density of *A. greggii* is also quite high (569/ha); *A. greggii* provide only 10.7% total percent cover. Of the other species found in plant community D, *A. canescens* and *C. pallida* are the most abundant (111/ha and 83/ha, respectively), and *C. linearis* provides the most cover (0.6%). The total percent cover provided by *H. monogyra*, *C. pallida*, *L. pallidum*, and *A. canescens* is less than 0.5% each.

The trunk diameters of the *P. velutina* population sampled at study site D display the greatest range of any species in any of the plant communities sampled in this inventory, with individuals in each size/age class from < 5 cm through 50.1–55 cm. The majority of trunk diameters are between 5.1 and 25 cm; individual trunk diameters range from 3.8–52.1 cm. The many mature *P. velutina* provide the large amount of cover at this site. The *A. greggii* population also encompasses a wide range of trunk diameters, although half of *A. greggii* sampled were very young (trunk diameters < 5 cm). This spread of trunk diameters indicates that both the *P. velutina* and *A. greggii* populations are comprised of a healthy mix of age classes. Trunk diameter breakdowns are not shown for the shrubs present because they are multi-stemmed with stem diameters not exceeding 5 cm.

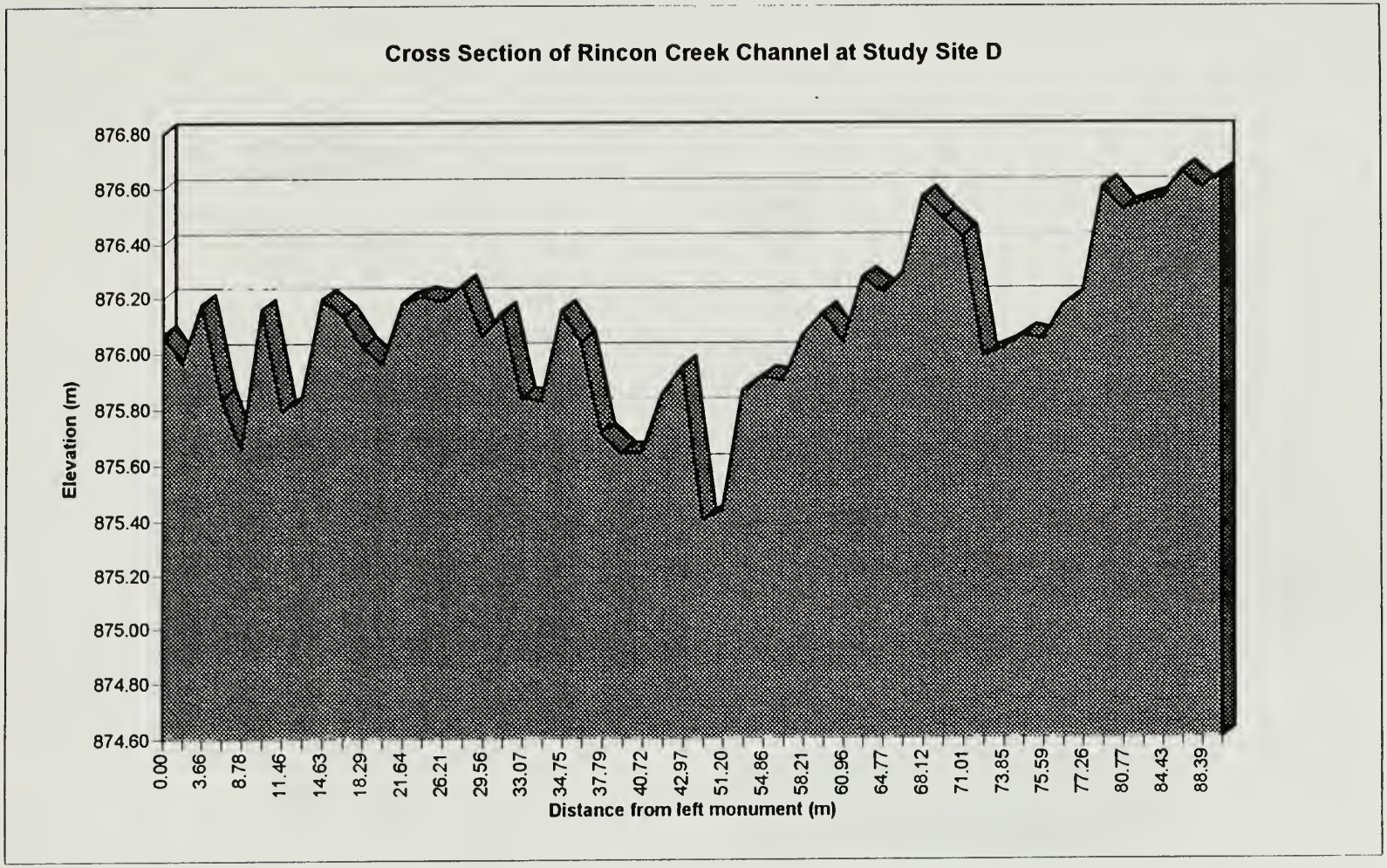

Figure 23. Cross-sectional profile of Rincon Creek channel at study site D.

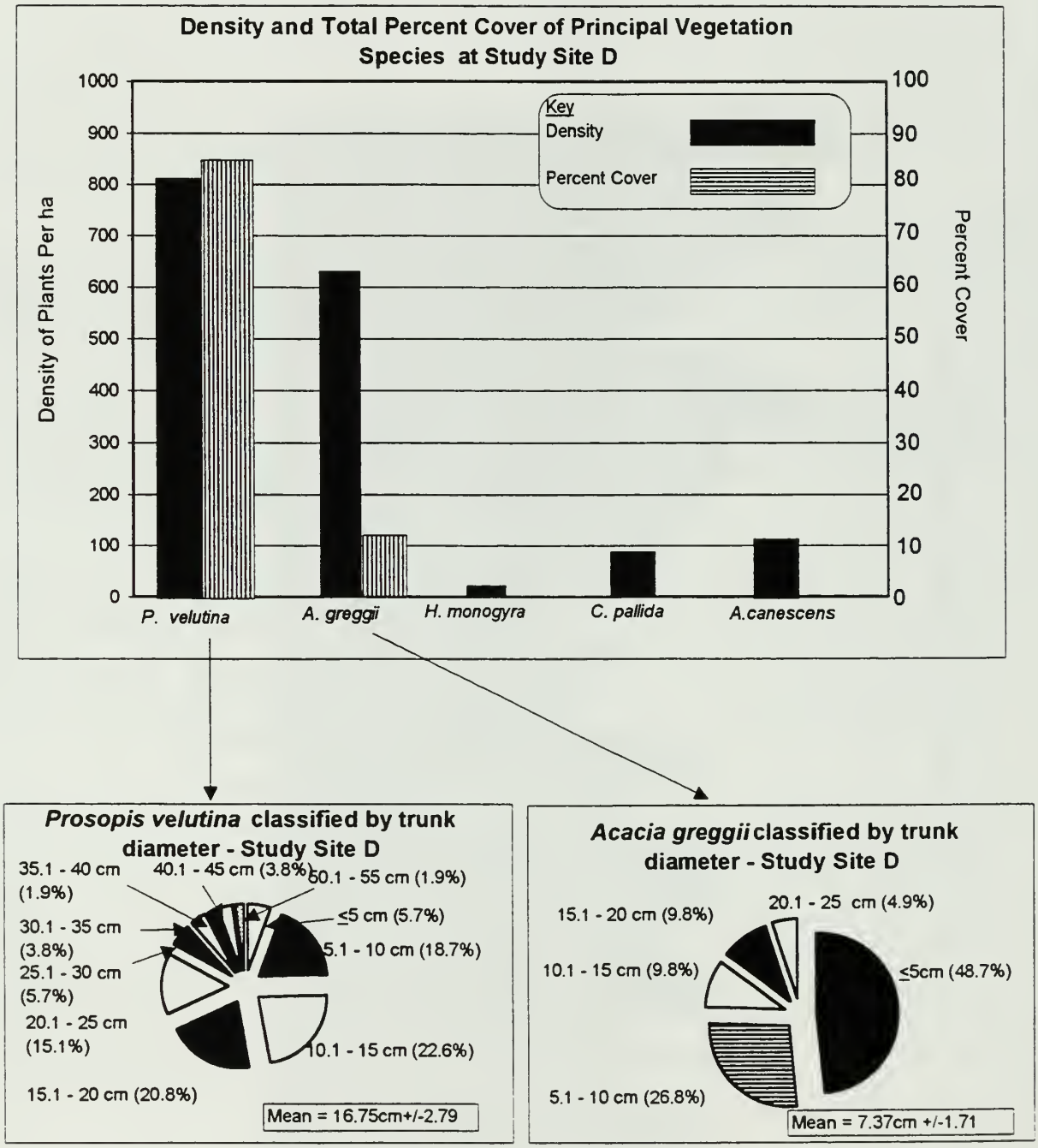

Figure 24. Summary of vegetation data collected at Rincon Creek study site D.

Hydrology

Streamflow *(Results of Crest Stage Gauge Monitoring)*

Over the 2-year period of the study, 5 Rincon Creek flow events were measured using crest stage gauges (Table 1). Three flow events occurred during the winter, when relatively lengthy precipitation events make streamflow more likely than do the flashy monsoonal summer rainstorms. Two of the 5 measurable flow events occurred during the summer. There are several reasons for the apparently low number of measurable flow events. First, bank-to-bank flow is required to calculate instantaneous discharge when using data collected from crest stage gauges. Along lower Rincon Creek, such flow occurs relatively infrequently. Second, there is a fine line between a flow event of insufficient magnitude for measurement and a flow event of a magnitude that is capable of damaging the gauges. During the course of the study, several of the gauges had to be repaired or replaced. In the dynamic environment of an unconfined alluvial stream channel, such undesirable consequences are almost unavoidable, unless considerable funding is available to install gauge supports to significantly greater depths. To address this issue, as well as the issue of improving the accuracy of streamflow measurements, the Rincon Institute is committed to securing funding for permanent and continuous flow data loggers.

In general, all of the instantaneous peak discharges calculated during this project period appear to be some what inflated. For example, the largest calculated instantaneous discharge of 160.52 m^3, which occurred at study site B during the night of 24 February 1995, surpasses 159.7 m^3/second, the highest peak discharge recorded for water year 1984 (a year of tremendous winter rainfall that far exceeded precipitation of 1995). Several factors can account for these inflated numbers, including recording error, an underestimation of the roughness coefficient, and/or an overestimation of the cross-sectional area of the wetted perimeter. Despite the seemingly high peak discharges, the numbers are relatively consistent with respect to the depth of recorded flow and calculated discharge. In other words, the data may not be reliable with regard to providing an accurate assessment of transmission losses between study site B and study site C, but the data do describe general correlations between the peak discharges that occurred at the 2 study sites.

For all 5 flow events, the peak discharges for the upstream site (study site B) were significantly greater than those recorded at the downstream site (study site C) during the same flow event. The greatest difference between upstream and downstream flow occurred during the February 1994 flow. For this event, instantaneous peak discharge at study site B was calculated at 122.72 m^3/second, over 3.5 times greater than the 34.69 m^3/second peak discharge calculated during the same flow event at study site C. This means that the flow event experienced a 71.7% decline in peak flow along the 4.4 km that separate the 2 study sites. In comparison, the December 1994 flow resulted in an upstream peak discharge of 20.45 m^3/second and a downstream peak discharge of 15.72 m^3/second, a reduction in peak discharge of 23.1%. Such large variations can be accounted for by a number of factors, including measuring error; inherent error in using crest stage gauges for determining instantaneous discharge; position of the peak discharge in the hydrograph (peak discharges occurring in saturated soils will likely experience smaller transmission losses than those in unsaturated soils); preceding precipitation conditions; and the fact that during high flow events a portion of flow exits the channel at some point between the 2

Table 1. Crest stage gauge readings and calculated instantaneous peak discharges at Rincon Creek study sites B and C.

Date Recorded	Study Site	Slope (m/m)	Roughness coefficient (n)	Cross-sectional area (m^2)	Hydraulic radius ($R^{2/3}$)	Depth (m)	Discharge (m^3/sec)
8/22/94	B	0.0074	0.029	13.88	0.3	0.67	38.29
	C	0.0068	0.037	14.91	0.76	0.17	18.84
2/22/94	B	0.0071	0.029	37.05	1.14	1.20	122.72
	C	0.0064	0.037	16.32	0.93	0.31	34.69
12/7/94	B	0.007	0.029	9.45	0.75	0.51	20.45
	C	0.0065	0.037	10.341	0.72	0.16	15.72
2/22/95	B	0.0071	0.029	43.5	1.27	1.44	160.52
	C	0.0065	0.037	22.82	1.11	0.42	55.19
8/25/95	B	0.007	0.029	13.9	0.94	0.67	37.76
	C	0.0063	0.037	12.84	0.88	0.23	24.24

study sites (and is therefore not measured at study site C, thus making the difference between the peak discharges calculated at the 2 study sites artificially large).

Although there are significant variations between the peak discharges for the flow events measured at the 2 study sites, the data seem to paint a picture of a stream system that experiences significant transmission losses along its lower reach. The August 1995 flow event, for example, experienced a 13.46 m^3 /second decline in peak discharge between study sites B and C. Since the 2 sites are separated by 4.4 km, this amounts to a 3.1 m^3/second decline in stream discharge per kilometer of channel reach. A rough estimation of the volume of water lost to the ground can be made by assuming a fixed time period. For example, if the peak discharge of the August 1995 flow lasted 15 minutes, over 2,790 m^3 of water would have been lost to the ground during this time period as the flow traveled between the 2 study sites. An even higher estimate of water loss between the 2 sites is calculated for the February 1994 flow event. This flow event would have lost roughly 79,227 m^3 of water to the ground if it had flowed for 15 minutes.

Such a dramatic reduction in discharge may be a major factor behind the apparent sediment problems that the lower reaches of Rincon Creek are experiencing. Reduced discharge with increased distance downstream is paralleled by a similar reduction in stream competence. As streamflow loses power, it loses the ability to move sediment. Sediment picked up along upstream reaches is then deposited along the lower reaches. Prolonged periods of aggradation along an unconfined alluvial stream channel can lead to an enhanced period of instability, characterized by abrupt changes in the channel's geometry.

It is interesting to note that only 60 years ago such dramatic transmission losses probably did not occur. Prior to the 1930s, groundwater levels were probably not significantly below the channel bed and may have even been above the elevation of the channel bed. Such relatively shallow groundwater characteristics would have contributed to base flow (meaning that prior to the 1930s, Rincon Creek probably flowed for much longer periods of time) and would also have been crucial to the survival and propagation of such riparian trees as *Juglans major*, *Populus fremontii*, and *Salix gooddingii*.

Sediment Movement (Results of Scour and Fill Chain Monitoring)

The data collected from the scour and fill chains do little to substantiate or repudiate the pre-inventory assessment that this reach was experiencing significant aggradation rates. Measured changes in chain positions during the course of the inventory demonstrated both increases and decreases of relative channel bed elevation (Table 2). Channel bed elevation changes range from an increase of 21.9 cm to a decrease of 21.6 cm. Overall, measured elevation changes tended to be predominantly increases in elevation rather than decreases; however, the limited amount of data and the inherent point-source characteristic of scour and fill chains make it difficult to strongly support this conclusion.

If scour and fill chains are to be used in future inventories, a greater number will need to be installed to gain a more complete picture of aggradation and degradation rates. Future surveys of channel cross sections will also provide information on sediment movement.

Groundwater

Depth to water level in all 3 wells varied little during the course of the study (Fig. 25). For example, the elevation of the shallow aquifer's potentiometric surface as measured in Well No.1 varied from a low of 881.7 m in November 1994 to a high of 887.2 m during July 1995. Although this shows a change of 5.5 m, the elevation of the aquifer's potentiometric surface at the first reading in June 1994 was very similar to the final measurement taken in March 1996: 882.8–882.5 m.

The data collected from Well No. 2 portrays a similar picture with regard to the extent of variation of the potentiometric surface of Rincon Valley's shallow aquifer. The lowest elevation was measured during July 1994 at 895.3 m; the highest measured elevation for Well No. 2 during the course of the study was 900.8 m, which occurred during September 1994. The difference in elevation between the first and final readings differed by only 0.2 m. The elevation of the potentiometric surface as measured in Well No. 3 varied even less. At Well No. 3, the difference between the highest elevation of the potentiometric surface to the lowest was only 0.3 m.

Due to their proximity to Rincon Creek, Well No. 1 and Well No. 2 probably provide the most accurate picture of how the depth to saturated soils varies immediately below the Rincon Creek channel. During the majority of the time that data were collected from Well No. 1, the depth to groundwater near study site B was approximately 19 m below the bed of the channel. At Well No. 2, depth to groundwater appeared to hover at roughly 8 m below the surface of the channel during the majority of the 2-year monitoring period.

Table 2. Data collected from scour and fill chains and computation of aggradation and degradation.

Location of Chain	Date of Previous Measurement	Date of Current Measurement	Amount of Scour (cm)	Amount of Fill (cm)	Total Elevation Change (cm)
C-1a	12-1-94	3-22-95	10.5	10.9	0.4
C-1a	3-22-95	5-18-96	9.0	9.0	0
C-1a	5-18-96	2-16-96	12.0	12.0	0
C-1b	12-1-94	3-22-95	8.9	8.2	-.7
C-1b	3-22-95	5-18-96	6.1	6.0	-0.1
C-1b	5-18-96	2-16-96	6.1	6.3	0.2
C-2a	12-1-94	3-22-95	9.5	9.8	0.3
C-2a	3-22-95	5-18-95	6.2	9.5	3.3
C-2a	5-18-9..6	2-16-96	12.4	13.7	1.3
C-2b	12-1-94	3-22-95	12.5	13.1	0.6
C-2b	3-22-95	5-18-95	0	3.0	3.0
C-2b	5-18-96	2-16-96	could not re-locate		
C-3a	12-1-94	3-22-95	8.1	30	21.9
C-3a	3-22-95	5-18-95	21.6	0	- 21.6
C-3a	5-18-96	2-16-96	15.0	17.0	2.0
C-3b	12-1-94	3-22-95	10.8	13.5	2.7
C-3b	3-22-95	5-18-95	14.6	8.8	- 5.8
C-3b	5-18-96	2-16-96	13.9	15.4	1.5

Generally, the groundwater data collected during this study agree with the assessment of Halpenny (1985), who concluded that the Rincon Valley aquifer system is slowly returning to a state of equilibrium following the cessation of large-scale groundwater pumping that took place during the 1950s and 1960s to support agricultural irrigation. The measured increase in water levels at Well No. 1 and Well No. 2 during the winter rainy season also supports Halpenny's assessment that water levels in the Rincon Valley (as in other aquifer systems in the region) rise during wet periods, decline during dry periods, and show little change over longer periods.

Nevertheless, depths of 8 m to saturated soils are still significant, particularly when one considers the water requirements of many shallow-rooted riparian trees (e.g., *Populus fremontii*). Although most mature riparian trees are able to acquire water from significant depths (e.g., the surviving mature *Juglans major* trees along lower Rincon Creek), it is unlikely that riparian plant seedlings can establish and survive in areas that no longer provide moist alluvial surfaces on a consistent basis during periods of natural seed-fall.

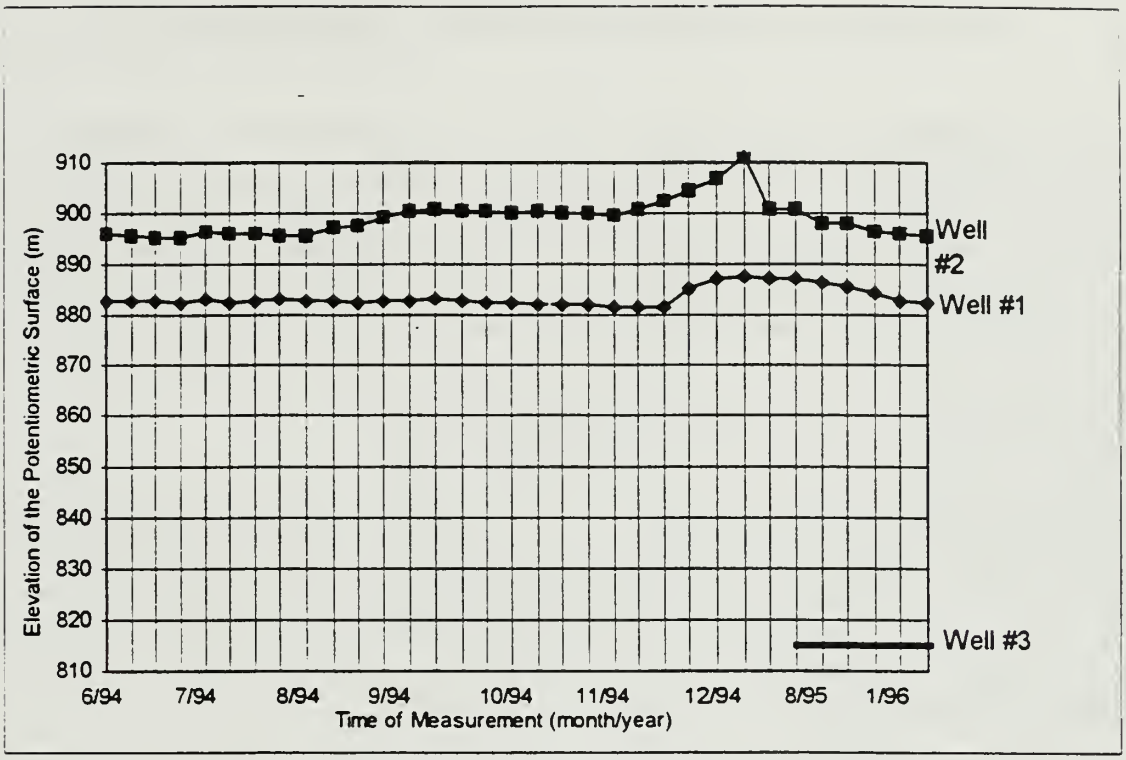

Figure 25. Elevation change in the potentiometric surface of Rincon Valley's shallow aquifer.

Observed Wildlife

Although a wildlife inventory was not conducted as part of this study, a variety of wildlife species was observed on and around the 4 study sites while carrying out surveys, inventories and monitoring activities. Bird species observed included *Geococcyx californianus*, *Melanerpes uropygialis*, *Campylorhynchus brunneicapillus*, *Toxostoma curvirostre*, several hummingbird species, *Pyrrhulaxia sinuata*, *Phainopepla nitens*, *Corvus corax*, *Cardinalis cardinalis*, *Buteo jamaicensis*, and others. A pair of *Bubo virginianus* and their 3 hatchlings were observed during the plant community inventory at study site D. Their nest was in a large *P. velutina* tree on the north bank of the widest channel bed. We also observed *Crotaphytus collaris*, other lizards (*Sceloporus* spp.), *Gopherus agassizii*, *Crotalus atrox*, *Phrynosoma* spp., *Canis latrans*, *Perognathus* spp., *Spermophilus tereticaudus*, *Dipodomys* spp., *Ammospermophilus harrisi*, *Syvilagus audubonii* and *Lepus* spp., *Tayassu tajacu*, *Odocoileus* spp., and 1 *Puma concolor*.

Conclusion and Management Recommendations

This initial step of a long-term riparian monitoring program describes in detail the riparian ecosystems of lower Rincon Creek prior to significant urbanization of Rincon Valley. In this effort, 4 study sites were established along a 12-km reach of lower Rincon Creek, extending from just downstream of the pediment of the Rincon Mountains to just upstream from its confluence with Pantano Wash. Data collected at each study site were used to describe current streamside vegetation communities and channel morphology. In addition, crest stage gauges and scour and fill chains were installed at several of the sites to gain a better understanding of the creek's current hydrologic characteristics, and 3 abandoned wells in the Rincon Valley were monitored to obtain a more complete picture of current depths to groundwater.

Moving in a downstream direction from study site A to study site D, the principal overstory plant species along Rincon Creek change from a mixture of *Populus fremontii*, *Salix gooddingii*, *Fraxinus velutina*, and *Platanus wrightii* to such species as *Prosopis velutina* and *Celtis reticulata*. Streamflow characteristics along this same reach change from perennial (or almost so) to ephemeral. With the exception of the reach that passes through the Rocking K Ranch, most of these changes are natural and for the most part reflect elevational gradients.

Collecting hydrologic, channel morphologic, and vegetative data both upstream and downstream from a site where intensive urbanization will occur in the near future (i.e., the Rocking K Ranch) will allow insights into some important riparian conservation issues. Some of the major questions that this long-term monitoring effort will shed some light on are:

How does significant urbanization in a formerly rural area affect runoff characteristics, and how will these changes affect nearby riparian ecosystems?

How will increased groundwater pumping affect groundwater levels, and in turn, how will groundwater decline affect local riparian plant communities?

Can riparian rehabilitation be effective along a damaged river reach in an urbanizing setting?

How will the overall structure (age class, diversity, percent cover) of the bottomland plant communities be affected as the Rincon Valley becomes urbanized?

What types of mitigation/conservation strategies will be effective in preventing or limiting damage to local riparian ecosystems from urbanization pressures?

Human-Related Changes to Lower Rincon Creek—a Summary

Generally, the reach of Rincon Creek included in this effort has not been significantly disturbed by human-related activities (i.e., streamside plant communities have not dramatically changed since the turn of the century), with the major exception being the reach that passes through the Rocking K Ranch. Anecdotal information from long-term Rincon Valley residents, aerial

photographs from 1936, and written historical accounts portray a bottomland environment much different from that which exists today.

Prior to the 1930s, the reach of Rincon Creek that passes through the Rocking K Ranch was dominated by *Juglans major*, with some trees exceeding 5 m in circumference, and experienced perennial to intermittent flow. These above-ground characteristics seem to indicate that the elevation of the potentiometric surface of Rincon Valley's shallow aquifer was higher then than it is today, possibly intersecting the Rincon Creek channel on a regular basis. According to residents and historical accounts, the creek's channel morphology prior to the 1930s was meandering to braided.

Beginning during the 1930s, various parts of the Rincon Creek bottom-lands were removed for agricultural purposes (primarily for the production of alfalfa and barley). By the mid-1950s, much of the "original" riparian plant community in the Rocking K Ranch no longer existed. The direct removal of riparian vegetation, extensive groundwater pumping for irrigation, channelization, and the impoundment of almost all of lower Rincon Creek's tributaries are probably the principal reasons behind the changes that have occurred.

Today, this reach of Rincon Creek is ephemeral, experiencing flow of short duration only after significant rainfall. Plant species characteristic of disturbed sites, such as *Isocoma tenuisecta* and *Hymenoclea monogyra* now dominate. Scattered remnants of *Platanus wrightii* and *Prosopis velutina* are all that remain of the former riparian woodland that once dominated this portion of Rincon Creek. The reach also appears to be highly unstable. Although much work remains to be performed to accurately describe the movement of sediment down Rincon Creek, initial evidence seems to indicate that this reach of Rincon Creek is significantly aggrading (W. Osterkamp, pers. comm., 1996). Essentially, flow along this portion of Rincon Creek no longer has the power to move sediment through (i.e., the amount of sediment entering this reach exceeds that which leaves it). Groundwater decline and the concomitant increase in transmission losses may be partially responsible. In addition, the impoundment of almost all of lower Rincon Creek's tributaries may be contributing to this problem.

A Geographical Information System

All of the information gathered for this initial inventory has been entered into a GIS database. The purpose of the database is twofold. First, the development of a GIS database will allow current and future natural resource practitioners to access and understand the information collected during this effort. Rincon Creek's current channel pattern and its relation to geographical and anthropogenic landmarks (e.g., tributaries, hilltops, roads, bridges, wells, etc.) have been accurately developed using up-to-date aerial photographs and topography maps. By "clicking" on various parts of lower Rincon Creek, users of the GIS will be able to access information describing the creek's hydrologic, channel morphologic, streamside vegetation, and groundwater characteristics as they existed in 1994–1996.

Second, the GIS will be an effective and efficient tool for comparing the results of future inventories to the data collected during this initial baseline effort. Not only will the results of future inventories be entered into the GIS, but the extent of urbanization occurring in the Rincon Valley will also be depicted. Combining natural resource data with information describing human-caused disturbances will allow GIS users to understand both the magnitude of changes to Rincon Creek's riparian ecosystems, as well as the reasons behind the changes that have occurred. Based on the results of several future inventories (to be conducted over the next 10 years or so), it is foreseen that a GIS model can be developed that will allow natural resource practitioners in similar environments to predict the consequences of various levels of urbanization on nearby riparian areas.

Determining When Change is Significant and the Reasons Behind the Changes

The baseline information that has been gathered for this report will be compared to the results of future inventories so that the extent of change experienced by the selected riparian areas of Rincon Creek can be understood. The principal reason for repeating these inventories is to gain a better understanding of how watershed disturbances, namely urbanization, affect the condition of riparian ecosystems. Data gathered allow a correlation between changes in Rincon Creek's riparian ecosystems and impacts from anthropomorphic disturbances.

Such comparisons bring up numerous questions regarding how changes in Rincon Creek's riparian ecosystems will be described and how the causes for the changes will be determined. In response to these questions, 2 general criteria are being assessed: anthropomorphic disturbances on the Rincon Creek watershed (assessed as urbanization intensity) and changes in Rincon Creek's riparian ecosystems (assessed by measuring changes in plant community parameters and hydrologic characteristics such as discharge and groundwater depth).

From the perspective of Rincon Creek's riparian ecosystems, the overriding question is one of determining the level at which change in a riparian ecosystem's vegetation characteristics become critical (or, in a statistical sense, significant). If the current inventory records 10 *Celtis reticulata* trees at a particular study site and the following inventory records only 6, does this constitute significant change? Or, does change only become significant when no *Celtis reticulata* trees are found? In addition, should the determination of significant change be made at the plant community level or at the species level?

On the other side of the coin, how are the causes of change in Rincon Creek's riparian ecosystems going to be determined? Riparian ecosystems are inherently dynamic, prone to dramatic changes in plant diversity and structure over short time periods (e.g., a statistically rare, high magnitude flow event can remove large quantities of riparian vegetation). Can changes due to such "normal" events be differentiated from changes due to human-related disturbances?

The answers to some of these questions may have to wait until the next inventory is performed. However, it is likely that the principal focus of analyzing change in Rincon Creek's riparian ecosystems will be at the plant species level, rather than at the community level. Criteria for evaluating and comparing plant communities have been developed on several fronts. Plant

diversity indices, for example, provide an overall indication of the variety of plants that make up a particular plant community. Score sheets that evaluate the habitat that a plant community provides to wildlife are also being used. In general, these broad evaluations boil down complicated criteria into 1 overall descriptive score. In the process, valuable information can be lost, clouding differences between baseline and future inventory data sets. In other words, dramatic changes can take place in the plant community without being reflected by a diversity index. It is important to note, however, that the data collection methods developed for this monitoring effort were developed with the idea that comparison analysis could be performed in several different ways, allowing project personnel to choose the analysis method that provides the most useful information.

The baseline data set describes the density, trunk diameter, and percent cover of the woody and succulent components of Rincon Creek's riparian plant communities. Change over time can therefore be analyzed at the level of the individual plant species. For all of the study sites, several key plant species (those species that were in the majority) will be chosen as indicators of overall change. For example, the manner in which *Prosopis velutina* trunk diameter at study site B changes over time may be a good indicator of how the streamside vegetation communities along that reach are changing as a whole. Whether change in *Prosopis velutina* trunk diameter is found to be significant can be determined by a two-tailed statistical test for the research hypothesis that no change in the mean trunk diameter has occurred between the 2 time periods. Percent cover and density can be compared over time in a similar manner.

To determine the extent to which change in Rincon Creek's riparian ecosystems can be attributed to human or natural events, how the Rincon Creek watershed changes over time also needs to be determined. To accomplish this task, the Rincon Institute and The University of Arizona have developed a GIS database model that incorporates scanned aerial photographs, allowing a variety of parameters from different time periods to be compared. For example, using the GIS technology to determine the extent to which the Rincon Creek watershed is covered by paved surfaces as development takes place will provide a good indication of urbanization's impacts on soil infiltration and runoff which, in turn, can be correlated to changes in Rincon Creek's hydrologic and vegetation characteristics.

Future Inventories

In differentiating between the natural year-to-year variation that takes place in riparian ecosystems and changes caused by human-related impacts, it is also important to emphasize that the Rincon Institute will continue low-intensity monitoring throughout the time period between inventories. Although the initiation of future vegetation and hydrologic surveys will be dependent on the procurement of outside funding, the Rincon Institute will continue to check crest stage gauges following flow events, take precipitation measurements and periodic groundwater measurements, and document dramatic changes in Rincon Creek's riparian ecosystems (due to fire or flooding, for example). In other words, databases from future inventories will be evaluated with a good understanding of major events that have taken place during the years since the last inventory.

It is appropriate for future inventories to be conducted at 2–3 year intervals, particularly when construction activities in the Rincon Valley begin in earnest. Of course, the precise timing of

future inventories will primarily be determined by the availability of funding. The Rincon Institute is committed to this long-term monitoring effort and finding the necessary funds to complete the next steps of this process. Since the baseline inventory has been completed, it seems likely that there will be interest to complete future inventories so that a comparison analysis can be performed. The opportunity to compare future inventories to the baseline database should facilitate the procurement of future monitoring funds.

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Appendix 1
Personnel

An inventory of riparian habitat along Rincon Creek united specialists in the fields of botany, ecology, hydrology, watershed management, and geographical information systems (GIS) modeling to determine and analyze the current condition of riparian habitats along a significant portion of Rincon Creek, Tucson, Arizona. The project manager conducted the majority of the fieldwork associated with this project. Each specialist oversaw data collection and helped determine how the data were analyzed. Below is a list of the individuals involved in this project and their qualifications.

William Halvorson, Unit Leader of the USGS Cooperative Park Studies Unit, The University of Arizona (CPSU/UA) and a plant ecologist, was the project supervisor. He has published extensively on topics related to the effects of various environmental factors on plant community distribution, structure, and function. One of his areas of expertise is how water and soil characteristics affect plant growth. He received a B.S. and M.S. in botany from Arizona State University and University of Illinois respectively, and has a Ph.D. in botany from Arizona State University.

Mark Briggs, M.S., project manager, is a biologist with the Rincon Institute. His research interests focus on evaluating the condition of riparian ecosystems and developing strategies for improving the condition of degraded riparian areas. His thesis evaluated the effectiveness of using revegetation to improve the condition of degraded riparian ecosystems in Arizona; he has recently written a guidebook for resource managers on how to evaluate degraded riparian ecosystems. He has been appointed to the city of Tucson's Urban Runoff Technical Committee to advise the City on ways to manage runoff while preserving natural ecosystems. He has a B.A. in biology from the University of Delaware and a M.S. in watershed management from The University of Arizona.

Randy Gimblett, supervisor of the GIS model, is an Assistant Professor of Landscape Architecture at The University of Arizona. His research interest focuses on the development and use of GIS for a variety of applications, including understanding environmental perception, simulation and visualization, and dynamic spatial models in investigating landscape processes and interaction. He has a Master's of Landscape Architecture from the University of Guelph and a DPLA from Ryerson Polytechnical Institute, Toronto, Canada.

Guy McPherson is an Assistant Professor in the School of Renewable Natural Resources, The University of Arizona. He is a terrestrial plant ecologist, and has conducted considerable research on basic and applied aspects of plant ecology. His teaching expertise includes courses in ecology and natural resources management. He is the author of over 50 publications, and has been recognized in American Men and Women in Science and Who's Who in Science and Engineering.

Waite Osterkamp is a research hydrologist with the U.S. Geological Survey, specializing in geomorphology and ecology of desert bottom-lands. He has directed numerous studies of geomorphic processes and has published widely on topics relating to fluvial processes, geomorphology of extreme events, vegetation, and groundwater hydrology. He has a B.A. in geology from the University of Colorado, an M.S. in chemistry from The University of Arizona, and a Ph.D. in hydrology from The University of Arizona. One of his current areas of interest is relating riparian vegetation characteristics to changes in channel morphology.

Bruce Roundy is Associate Professor of Range Management, School of Renewable Natural Resources, The University of Arizona. He has directed numerous studies of seed-bed ecology, and has published widely on the distribution and structure of salt desert plant communities. One of his areas of interest is studying the effects of revegetation on arid and semiarid rangeland.

William Shaw is Professor of Renewable Natural Resources and Wildlife Ecology at The University of Arizona. He has directed numerous studies of wildlife ecology, public interests in wildlife resources, and urban ecology. Shaw has published widely on topics dealing with urban wildlife and wildlife conservation, and was the recipient of the 1988 Daniel Leedy National Award for Urban Wildlife Conservation. He has a B.A. in biological sciences from the University of California at Berkeley, a M.S. in wildlife ecology from Utah State University, and a Ph.D. in natural resources from the University of Michigan.

Appendix 2

Data Collection Forms

Channel Morphology Data Collection Form

Study Area: _____ Transect #_____ Page _____ of _____

Investigators: _____ Date: _____

MEASURED VALUES (ft)				
Rod Position*	*Notes on Position*	Back-sight	Fore-sight	Elevation
0.0	(left monument)			

* *distance along transect (from left monument)*

Comments:

1 foot = 0.305 meters
1 meter = 3.28 feet

Plant Community Inventory - Data Collection Form
for
Vegetation Density, Diversity and Trunk Diameter

Study Area: _____ Transect #_____ Sample Plot #____ of ____ Plot Area: _____

Location of plot along transect line : _____
(describe and/or draw on back)

Investigator(s) _____ Date: _____

Species	Trunk Diameter*	Species	Trunk Diameter*

* ≤5cm, 5.1-10cm, 10.1-15cm, 15.1-20cm, 20.1-25cm, 25.1-30cm, 30.1-35cm, 35.1-40cm, 40.1-45cm, 45.1-50cm, 50.1-55cm, 55.1-60cm, or ≥ 60.1cm

Comments:

Plant Community Inventory - Data Collection Form for

Percent Cover

Study Site: _____ Transect #_____ *Page* ____ *of* ____

Line at Sample Plot #_____ of _____ Line Length: _____

Distance along transect from left monument: _____

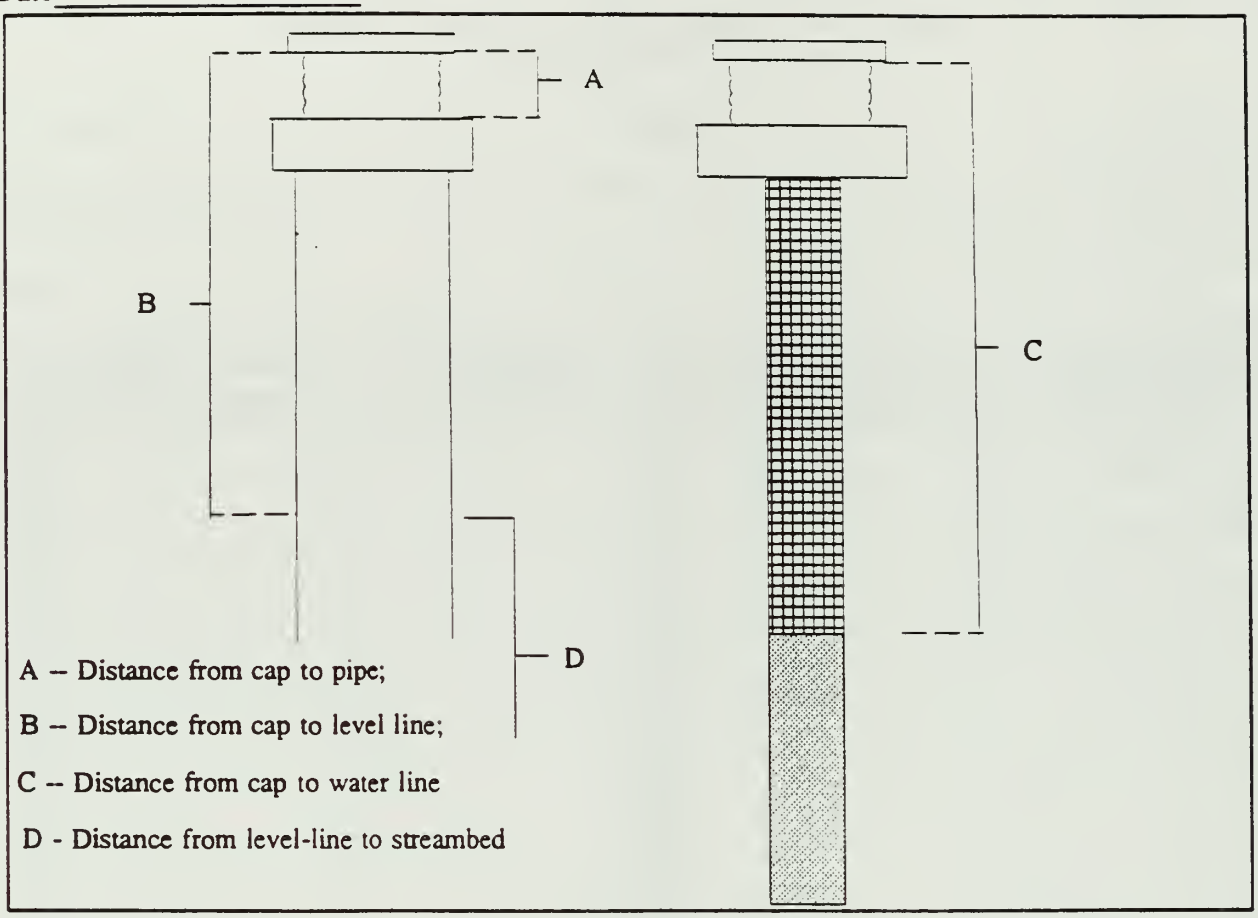
Investigator(s) _____ Date: _____

Species	Intercept Distance	Species	Intercept Distance
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-
	-		-

(Put comments and/or sketches on back)

Crest Stage Gauge Data Collection Form

Date_____


A
B
C
D
A -- Distance from cap to pipe;
B -- Distance from cap to level line;
C -- Distance from cap to water line
D - Distance from level-line to streambed

Gauge Id.#	Measured Distance			
	A	B	C	D*
S-1				
S-2				
S-3				
R-1				
R-2				
R-3				

* For measurement D on crest stage gages with two level lines, only measure the distance from the streambed to the lower line.

Comments:

S = Schultz R = Rocking K

Scour and Fill Data Form

Location of Chain	Date of Previous Measurement	Date of Current Measurement	Amount of Scour (cm)	Amount of Fill (cm)	Total Elevation Change (cm)

Groundwater Measurement Data Collection Form

Month and Year: _____

1. Well Name/Description: _____

a. Date: ___/___/___

b. **Calculate** the distance from well opening to water level:

1st try: tape extended to: _____ *ft* *Check (if necessary): tape extended to:* _____ *ft*

water line on tape at - _____ *ft* *water line on tape at* - _____ *ft*

distance from well opening to water level: _____ *distance from well opening to water level:* _____

Dstance from **well opening to water level**: _____ **ft**

c. **Subtract** the distance from **well opening to surface of ground**: - _____ **ft**

WATER LEVEL = [ ]

Comments:

2. Well Name/Description: _____

a. Date: ___/___/___

b. **Calculate** the distance from well opening to water level:

1st try: tape extended to: _____ *ft* *Check (if necessary): tape extended to:* _____ *ft*

water line on tape at - _____ *ft* *water line on tape at* - _____ *ft*

distance from well opening to water level: _____ *distance from well opening to water level:* _____

Dstance from **well opening to water level**: _____ **ft**

c. **Subtract** the distance from **well opening to surface of ground**: - _____ **ft**

WATER LEVEL = [ ]

Comments:

DATE DUE

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Clemson University
3 1604 012 038 271

The cover photog ational Monument by the first
National Park Ser (1891-1964).

As the nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting fish, wildlife and plants, preserving the environmental and cultural values of national parks and historic places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.